THE TRILLION DOLLAR ASSET

THE ECONOMIC VALUE OF THE LONG ISLAND SOUND BASIN

Long Island Sound Study
A Partnership to Restore and Protect the Sound

NEIWPCC
New England Interstate Water Pollution Control Commission

EARTH ECONOMICS

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The authors are responsible for the content of this report.

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NUMBERS AT A GLANCE

14 ecosystem services

on 9 land cover types

ANNUAL FLOW

$17 billion to

$36.6 billion

ASSET VALUE

$690 billion to

$1.3 trillion

4% over 100 years

Some call it nature—we call it natural capital. The population and economy surrounding the Long Island Sound depend upon a reliable supply of ecosystem goods and services. Marine transportation, commercial fishing, aesthetic beauty, and recreation are just a few of the many dividends provided by natural capital.

The Long Island Sound Basin's natural capital provides ecosystem service flows of at least $17 billion to $37 billion every year. Of 21 economically valuable ecosystem services present in the Basin, this study valued 14 across 9 land cover types. Benefit transfer methodology was applied using over 40 primary ecological economic valuation studies from the East Coast. Similar to valuations in financial markets, these studies made use of multiple valuation methodologies including market pricing, cost avoidance, replacement cost, travel cost, hedonic values, and contingent valuation. The range in values represents the lowest and highest possible values in the academic peer reviewed literature and can be used for comparison to other financial assets.

If the natural capital that generates this annual benefit were treated as a short-lived economic asset, **the asset value of the Long Island Sound Basin would be between $690 billion and $1.3 trillion** (4% discount rate over 100 years). But in truth, open space, forests, wetlands and estuaries are not short-lived, and do not depreciate or fall apart like vehicles, bridges, power plants, and other short-lived economic assets. Strategic and diversified investment in natural capital is a sound risk management strategy against climatic, social, and economic volatility. Additionally, this figure still omits many valuable natural asset benefits not included in this study or in current natural capital appreciation models.

This report seeks to inform both stakeholders and the general public about the economic value of the Sound and its watersheds, and to suggest policies and approaches that can maintain a healthy environment, society, and economy. Our current research updates the Long Island Sound valuation conducted in support of the 1994 Comprehensive Conservation and Management Plan (CCMP) produced by the Long Island Sound Study (LISS).

As for any traditional financial valuation, a paucity of data can lead to considerable underestimates of value. This examination of Long Island Sound's valuable ecosystem services will help expose data gaps where valuation data does not yet exist and help to guide and prioritize future research.

Understanding the scale of value of natural capital provides a vital perspective to decision-makers and the public. It helps inform the scale of dollar investment necessary for maintaining and improving the quality of natural assets. Wise investment in natural assets secures more resilient and sustainable returns in property values, food security, water quality, ecological and economic resilience, and other natural goods and services.

This study combines current data with the best available peer-reviewed ecological economics research. The results of this report can be used by a wide variety of stakeholders, including economists, educators, legislators, researchers, the public, and key decision makers, to educate and create consensus and to inform policy.

OBJECTIVE OF THE STUDY

The objective of this study is to provide useful information to the Long Island Sound Study, the New England Interstate Water Pollution Control Commission, and the general public to enhance the group's ability to make effective natural asset investments. To meet this objective we have:

- Identified natural assets within the basin and highlighted the importance of these assets to sustained economic development.
- Assigned monetary value to the ecosystem services in the basin within an economic framework of built and natural capital.
- Updated a valuation study that was conducted over 20 years ago.
- Presented recommendations of effective natural asset investments.

Understanding the scale of value of natural capital provides a vital perspective to decision-makers and the public.

RECOMMENDATIONS

Key recommendations include the following:

- Fill the Gaps: Fill in key gaps by conducting primary valuations for important ecosystems and services not yet documented.
- Return on Investment: Conduct return-on-investment analysis for Long Island Sound restoration and preservation strategies to inform the Comprehensive Conservation and Management Plan.
- Funding Mechanisms: Develop funding tools to generate the financial resources to sustain investment in Long Island Sound Basin natural asset enhancement strategies.

HOW TO USE THIS REPORT

This report has six sections:

- Introduction: includes a brief natural and human history of the Long Island Sound, an overview of the Long Island Sound Study's efforts, and Earth Economics' approach to valuation.
- The Long Island Sound Basin: details characteristics of the study area in terms of geography and demographics. Geographic Information Systems (GIS) methods are explained and a jobs analysis is included.
- Ecosystem Services in the Long Island Sound Basin: defines 21 ecosystem services with local examples.
- Valuation and Results: details Earth Economics' methodological framework and calculates dollar values for 14 ecosystem services, and provides an update to the 1992 Altobello Valuation Study.
- Recommendations: suggests new socioeconomic indicators for monitoring the health of the Sound's economy, society, and environment.
- Conclusion: summarizes the report to help the reader synthesize, understand, and apply the valuation.

The population and economy surrounding the Long Island Sound depend upon ecosystem goods and services. Pictured below is the coastline of Connecticut from Cove Harbor to Westport.

INTRODUCTION

WHY DO THIS STUDY?

Population growth and development have put a strain on the environment in the Long Island Sound (LIS) Basin in recent years. Pollution, toxic contaminants, and hypoxia (or low dissolved oxygen) are all problems in the Sound today. Over the past 25 years in the lower LIS Basin (Connecticut and New York portions), impervious areas have increased by 10.7%, while agricultural lands and wetlands have decreased by 13.9% and 4.3% respectively.[1] However, during this same time, government, individuals, and organizations have increased efforts to restore the health of the Long Island Sound.

Long Island Sound is one of North America's most urban yet biologically diverse estuaries: in 1987 the U.S. Environmental Protection Agency (EPA) recognized the Long Island Sound as an Estuary of National Significance. In recognition of this significance, the EPA, and the states of Connecticut and New York, formed the Long Island Sound Study (LISS) to accomplish the goal of restoring the health of the Long Island Sound. The state, federal, and other program partners are working to implement a Comprehensive Conservation and

FIGURE 1 MAP OF THE LONG ISLAND SOUND BASIN

Source: Long Island Sound Study

Management Plan, approved in 1994, to restore and protect the Sound. The LISS commissioned this study to support an update of this plan, expected to be completed in 2014.

INTRODUCTION TO ECOSYSTEM SERVICES

Ecosystem goods and services are defined as the benefits people derive from natural ecosystems.[2] Humans need ecosystem services to survive: breathable air, drinkable water, nourishing food, flood risk reduction, waste treatment, and stable atmospheric conditions are all examples of nature's services that are essential but often taken for granted.

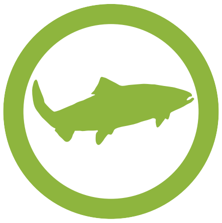
The benefits of ecosystem services are similar to other classes of economic benefits traditionally valued by economists, such as the services of skilled workers, mortgage flows from buildings, and car sales revenue.

These services are provided by the world's natural capital, which refers to the planet's reserve of water, air, land, and renewable and non-renewable resources. Just as with any form of capital, natural capital provides a supply of goods and a flow of services—the difference is these benefits stem from natural ecosystems. Goods are typically things you can "drop on your toe." Examples are lumber from the forest and water from a river that can be sold in markets. Services, on the other hand, can be described using measures other than physical quantity, such as the purification of air and water. Services are more accurately viewed as "natural capital dividends" that are delivered over time.

Ecosystem services can be classified into four broad categories as seen below. These four general categories include 21 specific ecosystem services. Table 1 lists the ecosystem services and their general categories.

PROVISIONING SERVICES provide physical materials that society uses. Forests provide lumber. Agricultural lands grow food. Rivers provide drinking water and fish for food.

REGULATING SERVICES are benefits obtained from the natural control of ecosystem processes. Intact ecosystems provide flood and hurricane risk reduction, regulation of climate, water quality and delivery timing, soil erosion or accumulation, and keep disease organisms in check. Degraded systems propagate disease organisms to the detriment of human health.



SUPPORTING SERVICES include services that are the basis of the vast majority of food webs and life on the planet. These include habitat and refugia for wildlife, primary productivity (i.e. natural plant growth) which supports habitat and food webs, and genetic materials which protect plants and animals from pests.

INFORMATION SERVICES are functions that allow humans to interact meaningfully with nature. These services include providing spiritually significant species and natural areas, natural places for recreation, scientific research, and educational opportunities.

TABLE 1 ECOSYSTEM SERVICE CLASSIFICATION

Provisioning Services	
ENERGY AND RAW MATERIALS	Providing fuel, fiber, fertilizer, minerals, and energy
FOOD	Producing crops, fish, game, and fruits
MEDICINAL RESOURCES	Providing traditional medicines, pharmaceuticals, and assay organisms
ORNAMENTAL RESOURCES	Providing resources for clothing, jewelry, handicraft, worship, and decoration
WATER SUPPLY	Provisioning surface and groundwater for drinking, irrigation, and industrial use

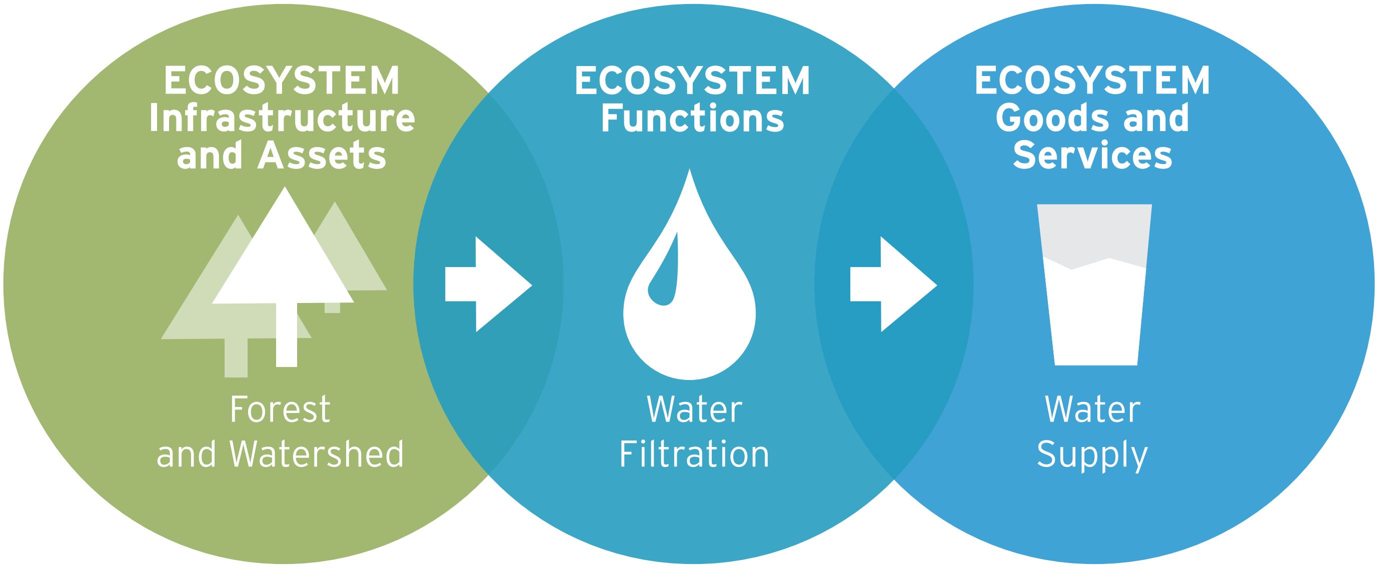
Information Services	
AESTHETIC INFORMATION	Enjoying and appreciating the presence, scenery, sounds, and smells of nature
CULTURAL AND ARTISTIC INSPIRATION	Using nature as motifs in art, film, folklore, books, cultural symbols, architecture, and media
RECREATION AND TOURISM	Experiencing natural ecosystems and enjoying outdoor activities
SCIENCE AND EDUCATION	Using natural systems for education and scientific research
SPIRITUAL AND HISTORICAL	Using nature for religious and spiritual purposes

Regulating Services	
AIR QUALITY	Providing clean, breathable air
BIOLOGICAL CONTROL	Providing pest and disease control
CLIMATE STABILITY	Supporting a stable climate through carbon sequestration and other processes
MODERATION OF EXTREME EVENTS	Preventing and mitigating natural hazards such as floods, hurricanes, fires, and droughts
POLLINATION	Pollinating wild and domestic plant species
SOIL FORMATION	Creating soils for agricultural use and ecosystems integrity; maintaining soil fertility
SOIL RETENTION	Retaining arable land, slope stability, and coastal integrity
WASTE TREATMENT	Improving soil, water, and air quality by decomposing human and animal waste and removing pollutants
WATER REGULATION	Providing natural irrigation, drainage, groundwater recharge, river flows, and navigation

Supporting Services	
GENETIC RESOURCES	Improving crop and livestock resistance to pathogens and pests
HABITAT AND NURSERY	Maintaining genetic and biological diversity, the basis for most other ecosystem functions; promoting growth of commercially harvested species

Adapted from: de Groot et al., 2002 and TEEB, 2009.[3,4]

FIGURE 2 THE LINK BETWEEN NATURAL INFRASTRUCTURE AND ECOSYSTEM GOODS AND SERVICES

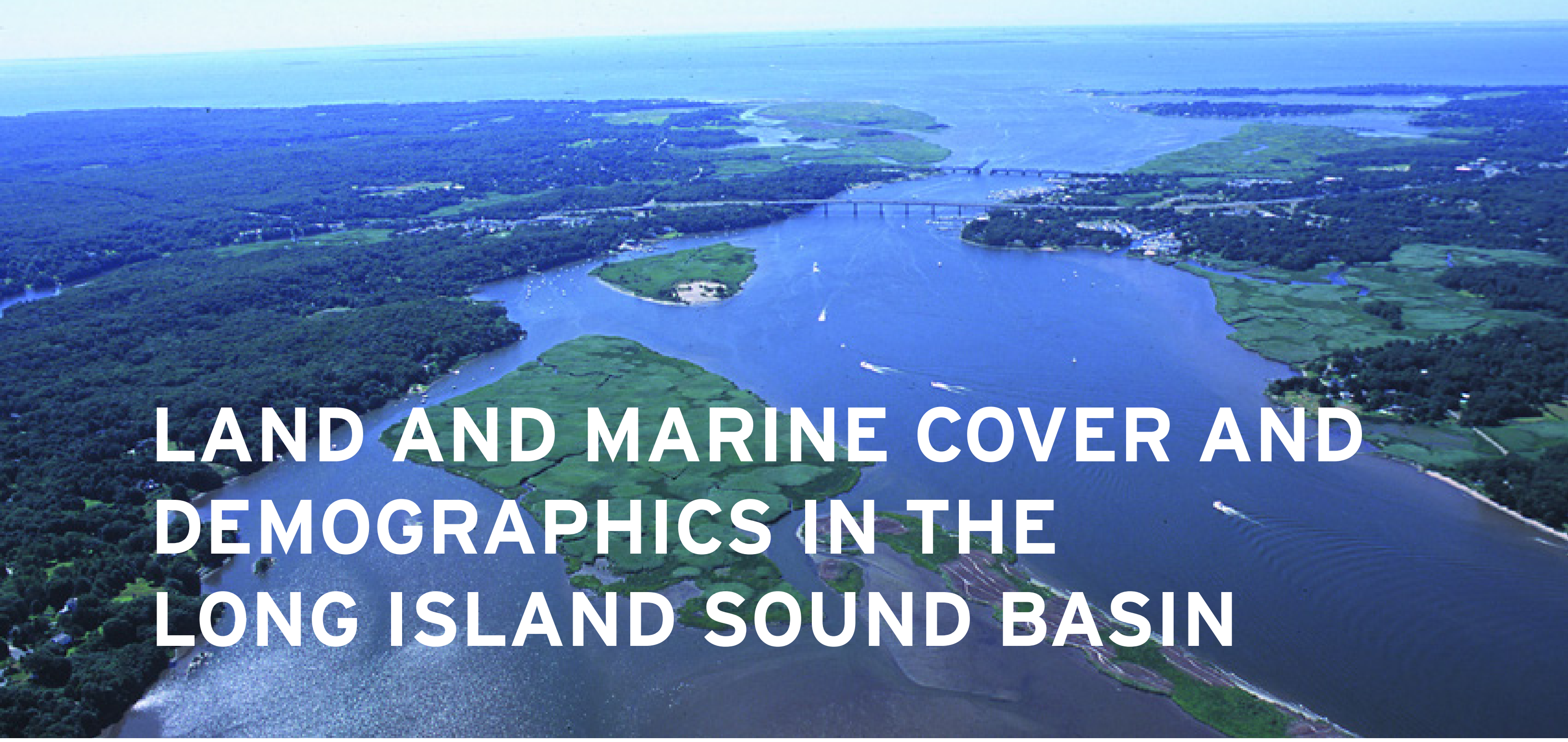


Forest ecosystems, for example, contain trees (natural capital assets), which intercept rainfall to filter water or reduce peak flood flows (functions). These functions in turn provide water supply (goods) and flood risk reduction (services). Figure 2 depicts the links of assets, functions, and goods for water supply.

New York City's water supply is derived from the forested Catskill watershed. By the 1980s, the water quality of the Catskill watershed was declining due to the pollution of the watershed, and the City would have had to filter its water to meet water quality standards. The filtration services would have cost $250 million annually, and construction of the filtration facility alone would have cost roughly $4 billion to $6 billion.[5] Instead of solving the problem with built capital, the City turned to natural capital investments. By implementing a watershed program, which reduced non-point source pollution and conserved the environments of the watershed, the city avoided the costs of building and maintaining the filtration system. Because the watershed acts as a substitute for water filtration systems, the City has access to a low cost, abundant water supply, spending only 1/8 of the cost of filtration that would be provided by a built facility.[5] The 2,000-square-mile water supply in the Catskills now serves 9 million people in New York City and its suburbs with 1.2 billion gallons of water per day, approximately 90% of the City's water needs.[5]

Losses of ecosystem services result in decreases in social and economic welfare. Economic losses include the impacts of jobs loss (e.g. collapse of the cod fishery), infrastructure costs (e.g. water filtration plants), restoration costs (e.g. best management practices), and loss of property or property value due to storm events such as storm surges and/or flooding (e.g. Superstorm Sandy).

> "... a good environment will produce good water."
>
> **Albert F. Appleton**
>
> Commissioner of the New York City Department of Environmental Protection (1990-1993)[5]



LAND AND MARINE COVER AND DEMOGRAPHICS IN THE LONG ISLAND SOUND BASIN

The Long Island Sound (LIS) is a large estuary on the East Coast of the United States bounded by Long Island to the south, New York to the west, and Connecticut and Rhode Island to the north with an open passage to the Atlantic Ocean on the east.[6] Water boundaries are at Battery Park in New York City to the west and The Race to the east. It is 21 miles wide at its widest point and 113 miles long. The surface area is approximately 1,300 square miles.[7] The Long Island Sound was originally home to several Nations of Tribal People including the Pequots, Mohegans, Wampanoag and the Pocumtucks.[8]

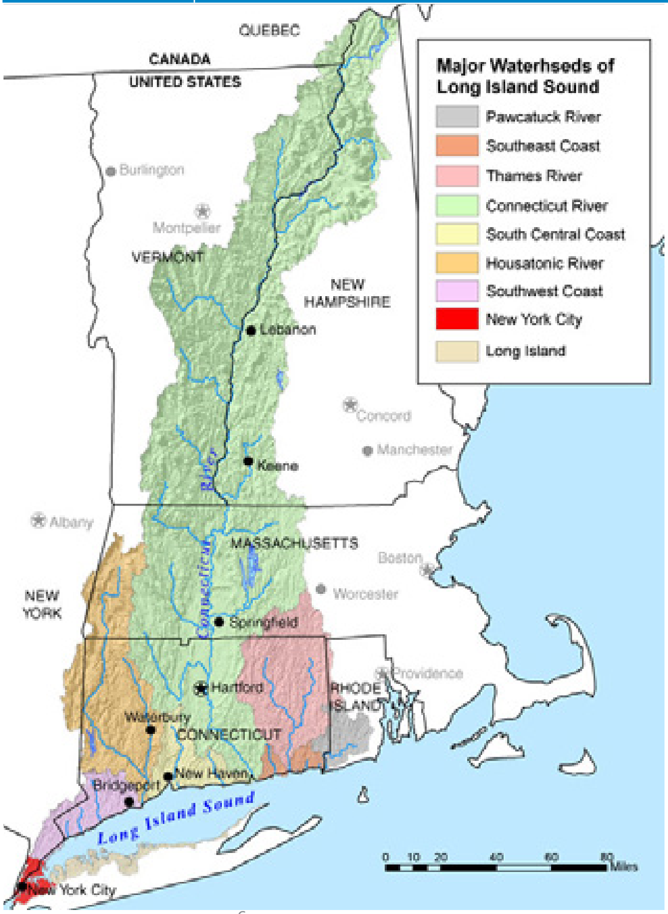
The Long Island Sound does not have a single source of freshwater. Additionally, the Long Island Sound is deeper on average (20 meters) than other major east coast estuaries. Freshwater sources input from all over the Sound, with the Connecticut River providing 75% of the gauged freshwater flow.[6] High salinity waters from the Atlantic Ocean enter the Sound at its eastern end through Block Island Sound, creating a mostly east to west gradient of salinity. The highly indented shoreline results in complex circulation patterns that yield an ecologically unique and economically valuable marine area.[9]

The Sound and its watersheds made colonial settlement viable, trade profitable, and a new nation possible. Having been referred to as the "American Mediterranean" and "The Urban Sea," the Long Island Sound is one of the most heavily used "nautical highways" in the world.[6] Today, shipping, recreation, commercial fishing, tourism, and real estate are each foundational elements of the region's economy.

STUDY AREA

The scope of this study encompasses Long Island Sound and its sub-watersheds. The lands that drain into the Sound cover an area of approximately 16,246 square miles, consist of more than 75 streams, and reach all the way into Canada.[10] The drainage basin contains most of the state of Connecticut, and parts of New York, Rhode Island, Massachusetts, New Hampshire, and Vermont (Figure 3). The only major sub-watershed not included in the study area for this report is the Pawcatuck River due to limited GIS data.

FIGURE 3 MAJOR WATERSHEDS DRAINING TO LONG ISLAND SOUND



Source: Tedesco et al. 2014[6]

Watersheds

The United States Geological Survey (USGS) defines a watershed as “the land area that drains water to a particular stream, river, or lake.”[11] The USGS classifies watersheds in hierarchical categories called hydrologic units (HUC).

There are nine major sub-watersheds that drain into the Long Island Sound, which includes smaller tributaries that drain into major rivers (See Table 2).

The water from these rivers flows into the Sound, depositing minerals, nutrients, soil, particles, and pollutants from upstream.

Watersheds are important to manage as their natural lands provide numerous ecosystem services. Development, especially in the form of sprawl, typically downgrades the complexity and service values of native ecosystems by converting them to turf, pavement, and ornamental shrubs. This creates an opportunity cost by losing natural services that would promote rainwater retention. The result is often the loss of fish and shellfish yields as well as an increased demand for built capital, like water treatment plants, levees, or irrigation systems that fulfill the functions nature once provided.

TABLE 2 WATERSHEDS AND MAJOR RIVERS OF THE LONG ISLAND SOUND BASIN

Sub-Watershed	Major River(s)	Acres	HUC Code(s)
New York		121,600	02030102
Long Island		592,000	02030201
Southwest Coast	Saugatuck	279,040	01100006
Housatonic	Housatonic	1,235,200	0110005
South Central Coast	Quinnipiac	330,240	0110004
Lower Connecticut	Lower Connecticut, Farmington, Westfield, Deerfield, Middle Connecticut, Miller, Chicopee	3,174,400	010802
Upper Connecticut	Upper Connecticut, Upper Connecticut-Mascoma, West, Black-Ottauquechee, White, Waits, Passumpsic	3,916,800	010801
Southeast Coast and Thames	Thames, Shetucket, Quinebaug	1,041,280	01100001, 01100002, 01100003
Pawcatuck	Pawcatuck, Wood	245,120	01090005

Source: USGS[12]

Land Cover

The spatial distribution of ecosystem services produced in the Long Island Sound Basin can be mapped across the landscape and water bodies. Each land cover type, from beaches to forests, provides its own unique suite of ecosystem services. As an analogy, mapping goods and services provided by factories, restaurants, schools, and businesses provides a view of the region's economy across the landscape.

This study used Geographical Information Systems (GIS) data to identify land cover types across the Long Island Sound Basin. GIS data are gathered through aerial and/or satellite photography. The United States Geological Survey 2006 National Land Cover Database (NLCD) was used as the foundational GIS layer. Table 3 presents the final land cover classes and acreages analyzed in this report, along with NLCD codes and description of the land cover class.

TABLE 3 LAND COVER ACREAGES FOR THE ENTIRE LONG ISLAND SOUND BASIN

Land Cover Class	Data Source(s)/ Layers Used	Definition	Area (acres)
Beach	Aerial Photography[i]	Beaches and dunes are the transitional sandy or cobble shoreline area between the land and the Sound. These dynamic systems are in a constant state of erosion and deposition due to tidal action, currents, and wind.	3,664
Estuary[ii]	Aerial Photography[i]	Estuaries include tidally influenced waters that have an open-surface connection to the sea, are regularly diluted by freshwater runoff from land, and exhibit some degree of land enclosure.	799,669
Cultivated	NLCD 81	Pasture/Hay: areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.	712,915
	NLCD 82	Cultivated Crops: areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.	
Forest	NLCD 41	Deciduous Forest: areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.	7,152,735
	NLCD 42	Evergreen Forest: areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.	
	NLCD 43	Mixed Forest: areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.	
Fresh water	NLCD 11	Open Water: areas of open water, generally with less than 25% cover of vegetation or soil.	254,761

[i] See appendix F

[ii] Definition adapted from Coastal and Marine Ecological Classification Standard (CMECS)

TABLE 3 CONT.	LAND COVER ACREAGES FOR THE ENTIRE LONG ISLAND SOUND BASIN		
Land Cover Class	**Data Source(s)/ Layers Used**	**Definition**	**Area (acres)**
Coastal wetland[iii]	FWS National Wetlands Inventory	Estuarine and Marine Wetlands describe wetlands adjacent to deepwater tidal habitats that are influenced by water runoff from and often semi-enclosed by land. They are located along low-energy coastlines and they have variable salinity.	3,474[iv]
Freshwater wetland[iii]	FWS National Wetlands Inventory	Palustrine wetlands include all nontidal wetlands dominated by trees, shrubs, emergents, mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean derived salts is below 0.5 ppt. Wetlands lacking such vegetation are also included if they exhibit all of the following characteristics: 1) are less than 8 hectares (20 acres); 2) do not have an active wave-formed or bedrock shoreline feature; 3) have at low water a depth less than 2 meters (6.6 feet) in the deepest part of the basin; 4) have a salinity due to ocean-derived salts of less than 0.5 ppt.	56,791
Grassland	NLCD 71	Grassland/Herbaceous: areas dominated by gramanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.	37,072
Seagrass	LISS	Eelgrass (Zostera marina) is a rooted underwater grass that grows along the coast.	2,061
Developed[v]	NLCD 21	Developed, Open Space: areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.	1,452,624
	NLCD 22	Developed, Low Intensity: areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.	
	NLCD 23	Developed, Medium Intensity: areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.	
	NLCD 24	Developed, High Intensity: highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.	
TOTAL			***10,475,766***

Source: NLCD 2006[13], LISS[14], FWS National Wetlands Inventory[15]

[iii] Ratios of wetland type were determined from the FWS National Wetlands Inventory and applied to total NLCD wetland acreages (NLCD 90 and NLCD 95)

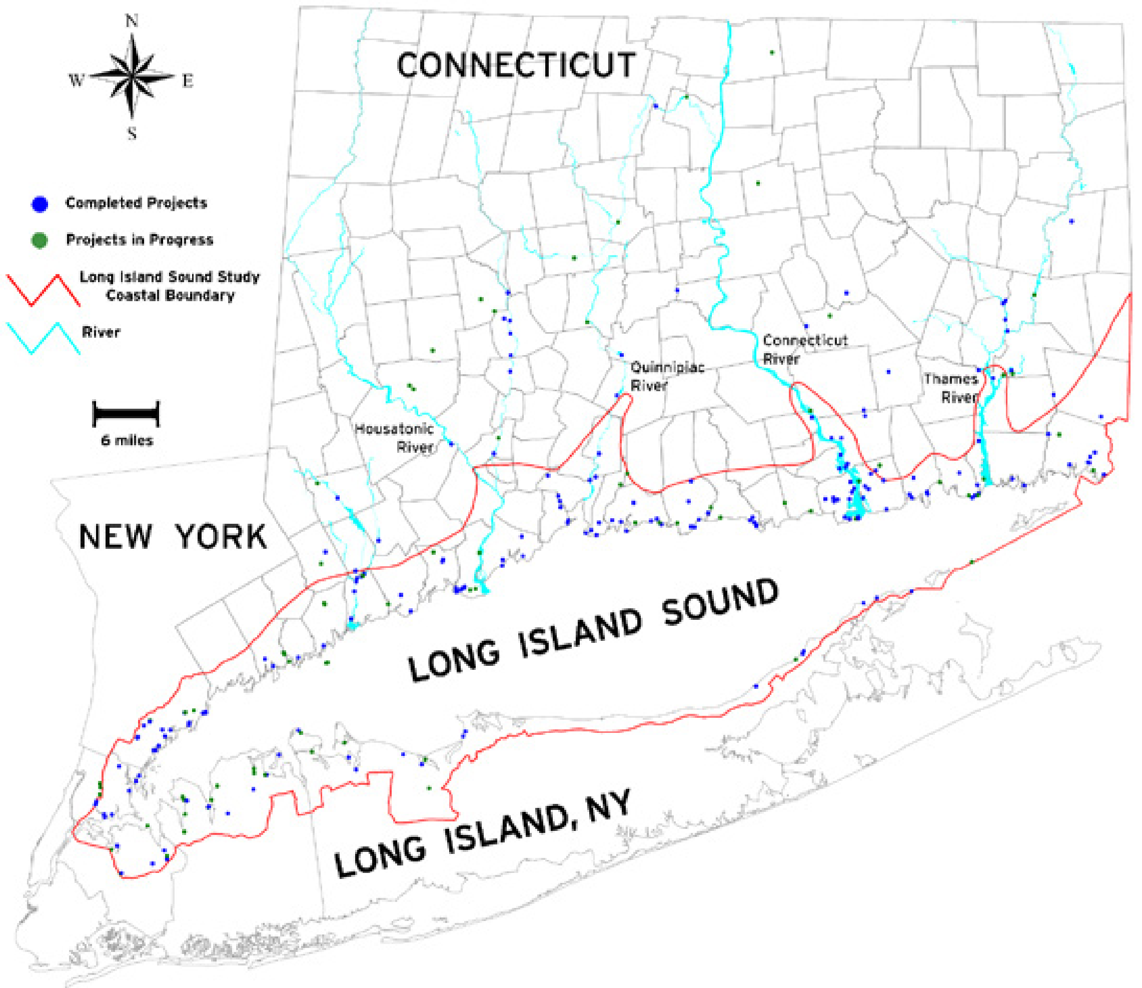
[iv] Palustrine coastal wetlands were included in the freshwater wetland category, thus the estimate for coastal wetlands appears lower than New York and Connecticut state listings which included freshwater Palustrine coastal wetlands

[v] Developed land cover was not included in the analysis

Restoration

The LISS Habitat Restoration Initiative (HRI) was adopted in 1998 with 12 priority habitats to improve habitat quality in the Long Island Sound region. The HRI was prepared as part of the LISS Comprehensive Conservation and Management Plan. The goal of the HRI is to restore at least 2,000 acres of habitat by 2020. From 1998 to July 2014, a cumulative total of 1,548 acres have been restored (including pending projects). This is 77% of HRI's goal (see Figure 4 for restoration projects). As restoration continues, the extent of some land covers will grow, increasing the total in Table 3.

FIGURE 4 RESTORATION SITES AROUND LONG ISLAND SOUND, 2002



Source: Harry Yamalis, Connecticut Department of Energy and Environmental Protection

Political Geography

The lower portion of the watershed includes most of Connecticut and parts of New York and Rhode Island. In these states, thirteen counties have lands within the watershed boundary.

The upper portion of the watershed crosses through parts of Massachusetts, Vermont, New Hampshire, and Quebec, Canada. In these states, fourteen counties have lands within the watershed boundary.

FIGURE 5 COUNTIES CROSSING THE LONG ISLAND SOUND BASIN

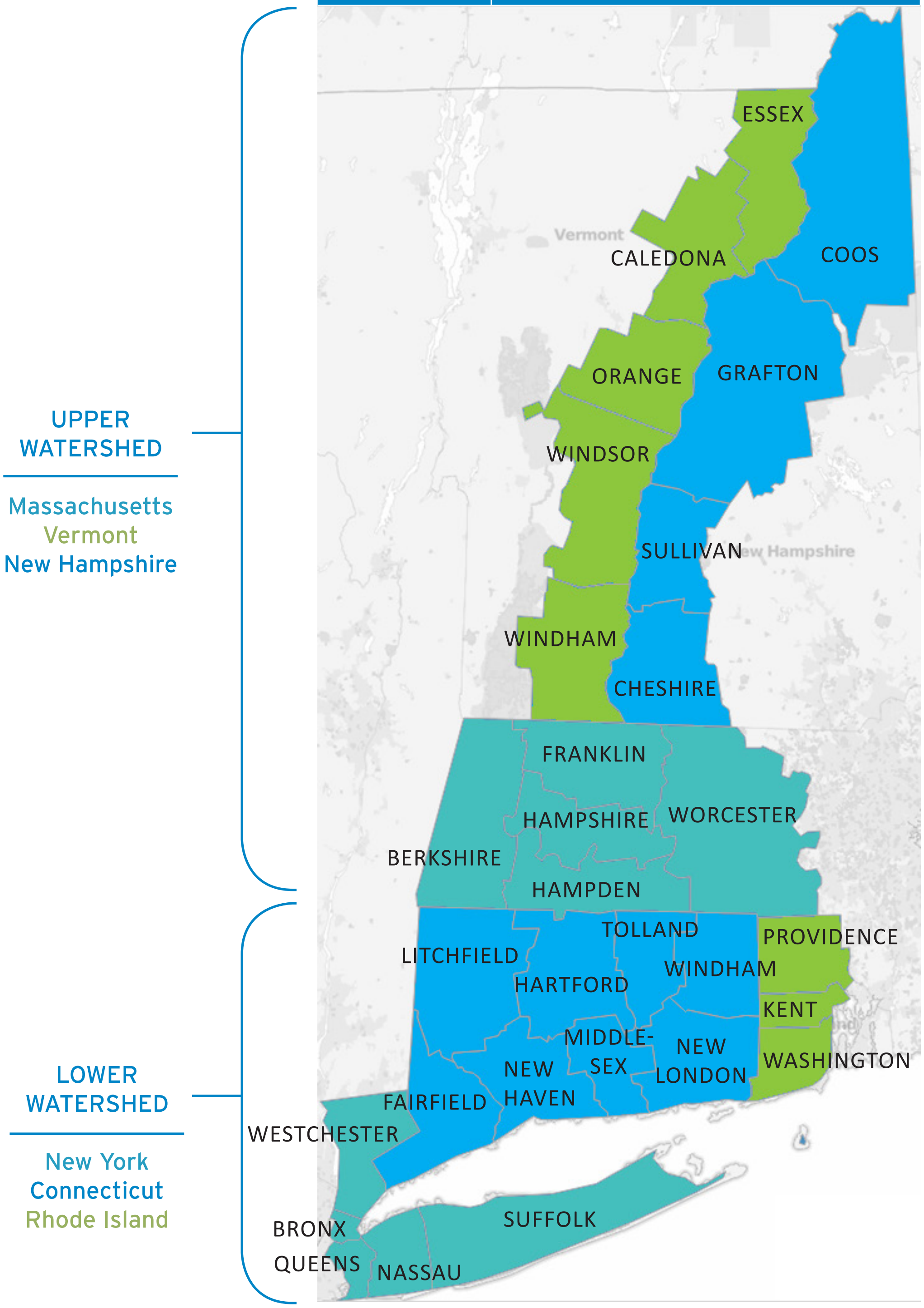


TABLE 4	JOBS AND WAGES DEPENDENT ON LONG ISLAND SOUND BASIN'S NATURAL CAPITAL, 2011					
State	**Direct Jobs**	**Indirect Jobs**	**Total Jobs**	**Direct Wages**	**Indirect Wages**	**Total Wages**
Connecticut	41,822	37,054	78,876	$2,390,517,905	$3,613,479,210	$6,003,997,115
New York	46,451	35,042	81,493	$2,251,194,023	$2,933,029,663	$5,184,223,686
Vermont	1,350	1,039	2,389	$38,145,135	$51,173,407	$89,318,543
Massachusetts	13,445	9,034	22,479	$434,840,671	$556,528,467	$991,369,138
New Hampshire	3,448	2,224	5,672	$110,562,347	$145,127,812	$255,690,159
Total	***106,517***	***84,393***	***190,910***	***$5,225,260,081***	***$7,299,338,559***	***$12,524,598,641***

Source: Earth Economics analysis based on IMPLAN 2011 data (see Appendix E)

Employment

While recent decades have seen a shift from agriculture and manufacturing to services, a vast number of critical industries and jobs still depend upon the ecosystems in which they are performed. These jobs and industries provide a foundation upon which the rest of the economy can grow. Analyzing the jobs and wages that depend on functioning habitats and natural resources provides an additional lens for understanding the importance of natural capital.

This study uses IMPLAN (IMpact analysis for PLANning) data from 2011 for five states in the Long Island Sound Basin. There are 135 industries included in the analysis (e.g., shellfish farming, wind power, and nature parks) that depend directly on natural capital. We found that over $5.2 billion in direct wages and over 190,000 jobs depend on the natural capital of the Long Island Sound and its Basin. See Table 4 and Appendix E for more information.

A vast number of critical industries and jobs still depend upon the ecosystems in which they are performed.

ECOSYSTEM SERVICES IN THE LONG ISLAND SOUND BASIN

There are 21 ecosystem services identified in the Long Island Sound Basin. In this chapter, each ecosystem service is divided into three parts: 1) general description 2) local reference 3) valuation approach. Many of the local examples come from the lower watershed, especially from the state of Connecticut; this is mostly due to data availability. An ecosystem service with an icon indicates that service is valued in the report. Those without it indicate data scarcity for the area.

PROVISIONING SERVICES

Food Provisioning

Description

Providing food is one of the most important benefits of natural ecosystems. Marine and estuarine waters provide opportunities for recreational and commercial fishing and agricultural lands provide crops and livestock.

Local Reference

Fish and shellfish such as herring, blue fish, oysters, clams, and lobsters are all harvested in the Long Island Sound. The commercial fishing industry generated more than 800 total jobs in Connecticut in 2010, while the total output impact was $65.1 million.[16]

Valuation Method

Economic value is given to food provisioning through market prices.

Shellfish such as oysters (left) are harvested in the Long Island Sound.

Medicinal Resources

Description

Plants and fungi produce chemicals that are utilized for medicinal applications. Many pharmaceuticals are derived from the compounds of these native plants.[17]

Local Reference

Native tribal people especially valued native plants with healing properties, since they were often the only medicines available. Early European settlers quickly learned medicinal wisdom from tribal people. Several native species of plants in the New England Region have been used historically for medicinal purposes (Table 5).

Approximately 18,000 natural products have already been extracted from marine species, and that number grows with each passing year.[18] Applications of these natural products apply to a wide range of disciplines, including agriculture, nutrition, cosmetics, industrial applications, and a variety of pharmaceuticals.

Valuation Method

Medicinal resources are typically valued through the market. It should be noted that species that do not have a direct economic value today may have future economic importance.

TABLE 5	SELECTED PLANTS NATIVE TO NEW ENGLAND AND THEIR MEDICINAL USES			
Common Name	**Species Name**	**Habitat**	**Distribution in New England**	**Historical Medicinal Use(s)**
Wild sarsaparilla	*Aralia nudicaulis*	Forests and woodlands	Native to northern New England	Blood purifier
Yellow wild indigo	*Baptisia tinctoria*	Woodlands, dry fields, sand plains, forest openings	Native to all New England, confined to southern part of the northern states	Antiseptic, reducing inflammation
Pink lady's-slipper	*Cypripedium acaule*	Forests and woodlands on acidic soils	Native from Canada to southern New England	Sedative
Boneset thoroughwort	*Eupatorium perfoliatum*	From tidal shores to forests in wet soil	Abundant throughout New England	Non-specific immune system stimulating properties
American witch-Hazel	*Hamamelis virginiana*	Deciduous and mixed forests	Native to all New England states	Astringent, antiseptic
Bladder-pod Lobelia	*Lobelia inflata*	Fields, clearings, and shorelines	Native to all New England states	Expectorant, bronchodilator, antispasmodic, muscle relaxant
Partridge-berry	*Mitchella repens*	Forests, usually evergreen	Native to all New England states	Astringent
Bee-balm	*Monarda fistulosa, Monarda punctata*	Fields, forests, clearings	Native in Connecticut, Massachusetts, and Vermont	Used to expel intestinal worms, appetite stimulant
King Solomon's-seal	*Polygonatum biflorum*	Forests, woodlands, riparian areas, fields	Native in Connecticut, Massachusetts, Maine, New Hampshire, Vermont	Aids musculoskeletal healing
Black elderberry	*Sambucus Canadensis*	Swamps, wetlands, stream banks	Native to all New England states	Diuretic, laxative
Large cranberry	*Vaccinium macrocarpon*	Bogs, fens, marshes, lake shores	Native to all New England states	Prevents and fights urinary tract infections
Perfoliate bellwort	*Uvularia perfoliata*	Deciduous forests	Native to Connecticut, Massachusetts, New Hampshire, Rhode Island, Vermont	Cough medicine, soothing sore or inflamed mouth

Source: New England Wild Flower Society[17]

Ornamental Resources

Description

Both terrestrial and marine ecosystems provide resources for clothing, jewelry, handicraft, worship, and decoration.

Local Reference

The native tribes' form of money for material, political, and ceremonial transactions was known as wampum, a beautiful artistic bead work fashioned from the North Atlantic channeled whelk shell (*Busycotypus canaliculatus*) and the white and purple beads made from the quahog, or Western North Atlantic hard-shelled clam (*Mercenaria mercenaria*). Many animals that live in the Sound are considered beautiful and are collected by tourists and residents who visit local beaches. Common seastars, like the Forbes seastar (*Asterias forbesi*), are just one example used in seaside decorations. Driftwood, sea glass, coral, stones, and dried sea plants are all materials used in craftmaking.

Valuation Method

Looking at market prices is the best way to value these ecosystem goods. Other regional ornamental resources include pumpkins, decorative corn and squash, flowers, winter holiday wreaths, and garden shrubbery, all of which provide significant employment and income to many communities.

Native tribes fashioned wampum from the Northern quahog.

Energy and Raw Materials

Description

Natural capital provides materials and energy. Raw materials include all wood and wood products, such as paper, lumber, and wood chips, as well as quarried and mined materials like crushed stone, marble, granite, and sand. Soil additives including manure, topsoil, compost, and mulch are other such materials derived from nature.

Local Reference

According to the U.S. Energy Information Administration, nearly 20% of New England homes continue to use wood for home heating, water heating, or cooking.[19] In Long Island Sound, bioextraction of a native red seaweed (*Gracilaria*) can potentially provide raw materials such as sea vegetables and biofuel, among other ecosystem services.[20]

Valuation Method

Energy and raw materials are bought and sold through the marketplace. Value is derived from market prices.

This native red seaweed has the potential to provide raw materials.

Water Supply

Description

Surface and groundwater for drinking, irrigation, and industrial use.

Local Reference

Many of the Connecticut River's tributaries recharge reservoirs for drinking water supply to residents, as well as groundwater and aquifers for agricultural, industrial, commercial, and power generation uses.[21] Overall, the Connecticut River watershed contains more than half a million acres of land used for water supply (Table 6).

TABLE 6 WATER SUPPLY AREA IN THE CONNECTICUT RIVER WATERSHED

State	Water Supply Area (acres)
CT	77,841
MA	240,623
NH	202,902
VT	No data available
Total	***521,366***

Source: Clay et al. 2006[21]

For example, the Swift River, one of the Connecticut River's tributaries, forms the Quabbin Reservoir in western Massachusetts. The Quabbin Reservoir is one of the largest unfiltered water supplies in the world, and one of the largest man-made public water supplies in the US.[21] The reservoir is capable of holding a 4-year supply of water, with a capacity of 412 billion gallons and an area of more than 24,500 acres, and is the primary water supplier for the city of Boston and 46 other communities in central and east Massachusetts.[22]

Valuation Method

Water pricing largely depends on location and use. Market value is the most common method to assign a price to water supply.

REGULATING SERVICES

Biological Control

Description

Natural predators can greatly reduce the densities of pest species and so reduces the use of pesticides in agriculture.

Local Reference

Organic farming practices depend to a greater extent upon natural pest control services to keep pest populations below economic threshold levels. For example, bats can eat 4 to 8 grams (the weight of about a grape or two) of insects each night.[23] One million bats in the Northeast could potentially eat between 660 and 1,320 metric tons of insects each year.

Valuation Method

By avoiding paying for pesticides, a farmer saves money.

Climate Stability

Description

Terrestrial and marine ecosystems stabilize the climate through a combination of exchanging gases, fixing carbon, regulating moisture, modifying airflows, and emitting aerosols. Marine systems that sequester carbon, known as "blue carbon," fix it from the atmosphere on the time scale of millennia.[24]

Local Reference

Pine trees, like those found in the boreal forests of New England, emit low volatility aerosol compounds into the atmosphere that reflect sunlight back to space and readily condense moisture, thus promoting cooling and the formation of clouds.[25] From all the world's biological carbon captured, more than 55% is captured by marine systems, i.e. coastal wetlands, seagrass beds, and nearshore vegetated areas, which are all present in the Long Island Sound.[26] Table 7 shows the rates at which carbon is removed by several blue carbon sinks present in the Sound.

TABLE 7	CARBON SEQUESTRATION RATES BY BLUE CARBON SINKS	
Component	**Average Carbon Sequestration (t C/ha/y)**	**Global Carbon Burial (tG C/y)**
Salt Marsh	1.51	190
Seagrass	0.83	82
Estuaries	0.5	81

Source: Nellemann et al., 2009[26]

t C/ha/y = metric tons of carbon per hectare per year
tG C/y = teragram of carbon per year

Valuation Method

There are several ways economists place a value on carbon sequestration and storage. Voluntary markets are where prices can be derived. Another way of valuing carbon is to look at the social cost of carbon, which is meant to be a comprehensive estimate of climate change damages and includes, but is not limited to, changes in net agricultural productivity, human health, and property damages from increased flood risk.[27]

Air Quality

Description

Trees filter air by removing gaseous pollutants and other particulate matter, such as ash, dust, pollen, and smoke, which are damaging to human lungs. In addition, trees produce oxygen, replenish the atmosphere, and help maintain humidity necessary for the formation of clouds. One acre of forest cover provides oxygen to sustain 18 people per day.[28]

Local Reference

Forests are beneficial to the people in the Long Island Sound Basin through trees that trap airborne particulate matter and thus improve air quality. In Connecticut where forests account for close to 60% of the land,[29] forests contribute to the state's good air quality.

Valuation Method

Economic value can be attributed to air quality by looking at what cities spend on alternative dust control programs.

Moderation of Extreme Events

Description

Floodplain forests are common wetland ecosystems that cover extensive regions of the Connecticut and Housatonic rivers. They act as natural water storage areas and can reduce catastrophic flooding.[30,31] During floods, water spreads over the floodplain and loses velocity resulting in reduced risk of downstream damage. Different types of floodplain forests contribute to flood risk reduction differently.

Local Reference

Large river floodplain forests occur along the banks of rivers, such as the Connecticut River, originating from watersheds of 617,800 to 7,413,200 acres in size and are characteristically along rivers navigable by boat.[31] These wetlands make immense contributions to flood risk reduction because of their ability to store floodwater for long durations. Forests in the low floodplain tend to flood annually or bi-annually for more than 10 days at a time.

High gradient river floodplain forests occur around river channels that have high flow velocities.[30] Typical high-flow areas include the White River in Vermont, the Wild Ammonoosuc River in New Hampshire, and Hart Island on the Connecticut River. In this type of wetland, floodplain forest vegetation is important for slowing frequent, but short duration floods.

Valuation Method

Wetlands' ability to absorb floodwaters or buffer storm surges can be valued by looking at the avoided costs that would have been incurred in the absence of these natural systems.

Pollination

Description

Pollinators are essential to the reproduction of flowering plants, and thus to the quantity and quality of agricultural production. In the wild, pollinators increase food sources for wildlife.[32] Bees are the best documented pollinators for natural and agricultural landscapes in the Long Island Sound region.

Local Reference

A large proportion of the native bees in the Long Island Sound region are digger bees—solitary bees that nest in the ground.[32] Solitary digger bees burrow in the ground to make nests, but each nest holds only one bee, unlike the social honeybee, which forms colonies. Digger bees collect pollen to feed their brood, and as a result of their fuzzy bodies, are excellent at transporting pollen between plants. They are important pollinators in the area, especially for pollinating blueberries since they often burrow in blueberry fields.[33]

Valuation Method

Valuation can be attributed to pollination by looking at how much it would cost to replace the service provided by pollinating species.

Digger bees are important pollinators in the study area.

Soil Formation

Description

Soil formation processes include the chemical weathering of rocks and the transportation and accumulation of inorganic and organic matter. Sediment creates and maintains nearshore habitats critical for the survival of fish and invertebrates, sustains beaches, and allows seagrass beds to thrive in shallow, low tidal areas.[34]

Local Reference

Headland erosion is an important process that contributes to the formation of beaches in the Long Island Sound. Bluffs in Nassau and Suffolk counties in New York are constantly eroded by wind and water at a rate of about one to two feet per year.[35] The loose sand and cobble resulting from this action forms beaches at the base of the bluffs called headland beaches. Bluffs in New York typically deposit sediment onto beaches, which ranges in size from fine-grained sand to gravel. More cobble beaches are seen here at the foot of bluffs than sand beaches farther to the west of the Sound.

Headland beaches are then eroded and the sediment is carried away by currents and waves. This sediment is an important addition to the sand budget for beaches all around the Sound.[35]

Valuation Method

Market based methods are appropriate for valuing soil formation. Looking at the price of top soil, transportation and labor expenses associated with the replacement can be attributed to this ecosystem service.

Sand from bluffs and beaches is redistributed to other beaches throughout the Long Island Sound.

Sediment spewing from the Connecticut River into Long Island Sound. Riparian buffers stabilize stream banks and prevent erosion.

Soil Retention

Description

Soil retention helps retain arable land, slope stability, and coastal integrity through having adequate vegetation cover, root biomass, and soil biota.

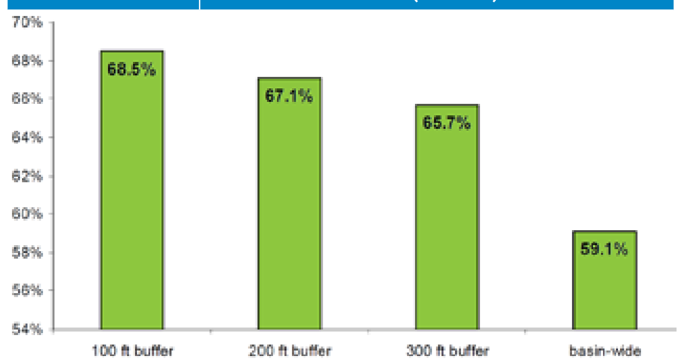
Local Reference

One example of the benefits of soil retention lies with riparian buffers. It is important that riparian vegetation—vegetation located adjacent to water bodies—remains intact; riparian zones should have more natural vegetation closer to streams. Riparian buffers cannot provide the service of soil retention without natural vegetation. The roots of riparian vegetation, such as trees and shrubs, help stabilize stream banks that, if eroded, could damage downstream property and ecosystems. Additionally, eroded stream banks can pollute the river with suspended particles. Riparian grasses are also effective at keeping sediment, nutrients, pesticides, and pathogens out of the stream, thus improving water quality. Overall, natural vegetation declined in riparian areas in coastal Connecticut from 1985 to 2002. Natural vegetation decreased by 2.6% inside the 300-foot buffer zone, by 2.2% in the 200-foot buffer zone, and by 1.6% in the 100-foot buffer zone.[36]

Valuation Method

One way to value soil retention is by looking at the avoided costs of replacing topsoil. This market-based approach can be measured by looking at tons of soil conserved or released per year.

FIGURE 6 PERCENT NATURAL VEGETATION IN RIPARIAN BUFFERS OF VARYING WIDTHS IN CONNECTICUT (2002)



Source: Center for Land Use Education and Research[36]

Waste Treatment

Description

Nutrient pollution, especially nitrogen, fuels the boom-and-bust growth of tiny algae called phytoplankton.[37] If oxygen levels fall too low, water is incapable of supporting fish and other aquatic life. Several ecosystems provide natural pollution treatment and storage, including wetlands, riparian areas, and floodplain forests, which helps improve water quality. Wetlands can help mitigate hypoxia by reducing nutrient loading in rivers and streams that lead to water bodies.

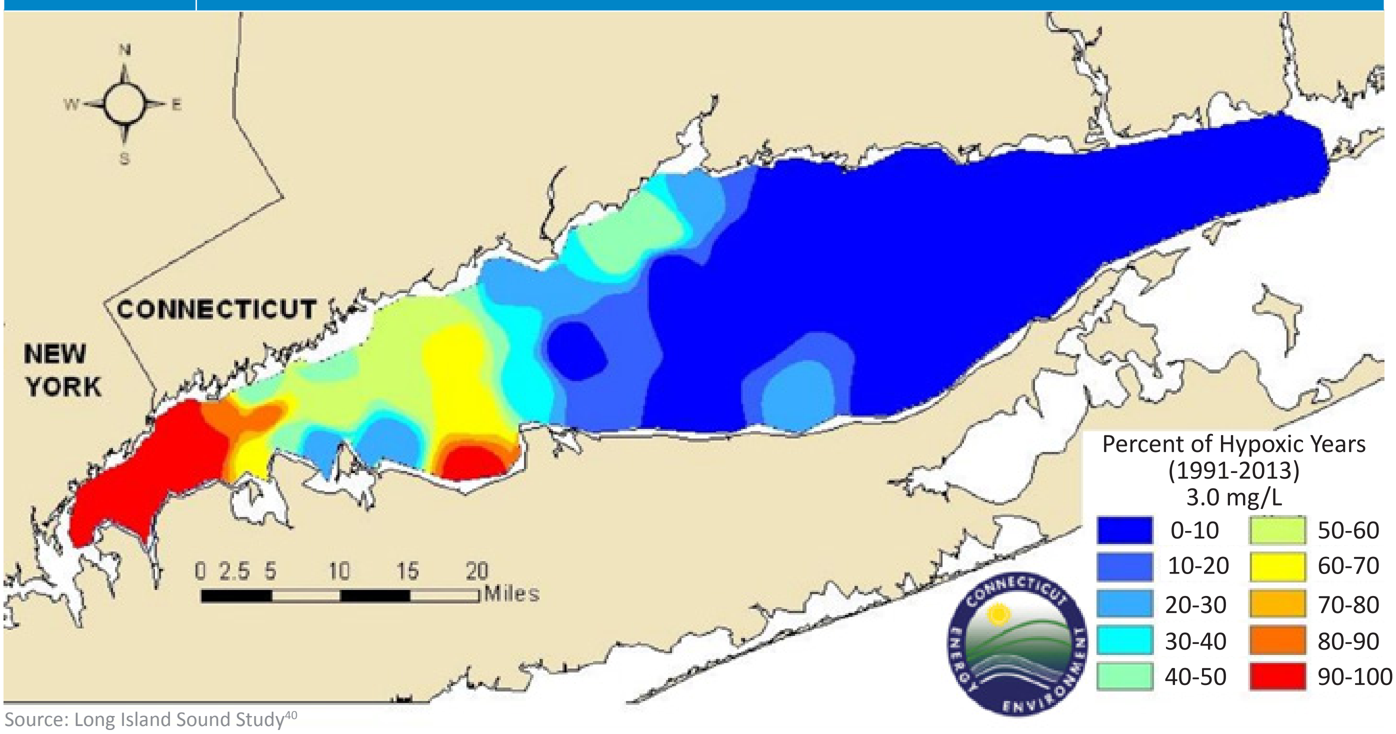
Local Reference

Human activities have been identified as the primary source of excessive nitrogen in the Long Island Sound, which causes major water quality issues, including hypoxia—or low dissolved oxygen.[38] Nitrogen sources include sewage treatment plants, septic systems, air pollution that is deposited on the watershed and the Sound, and runoff from urban and agricultural areas.[37] The Long Island Sound experiences hypoxic conditions each summer, especially in the west end (Figure 7). Shellfish, like oysters, serve to regenerate large quantities of nitrogen to the water column.[39] The process of oyster biodeposition, burial of its waste, can also enhance the permanent removal of nitrogen and phosphorus from the water column.

Valuation Method

Economic value can be attributed to the cost of reducing nitrogen from the water column to meet water quality goals. The value of oyster beds can be valued by looking at the costs avoided by the alternative methods.

FIGURE 7 FREQUENCY OF HYPOXIA IN LONG ISLAND SOUND BOTTOM WATERS



Source: Long Island Sound Study[40]

Water Regulation

Description

Ecosystems influence the timing and magnitude of water runoff, natural irrigation, and aquifer recharge, especially in terms of the water storage potential.

Aquifers are permeable and porous geological formations in which water can move through easily. This water is called groundwater because it occurs below the surface of the Earth.[41]

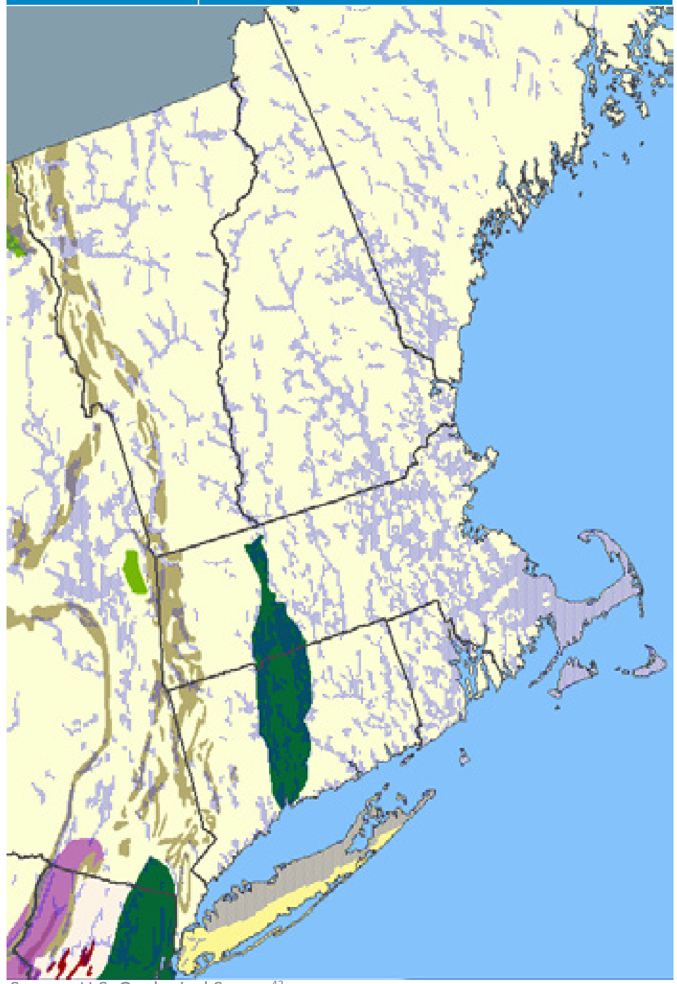
Local Reference

New England gets its water from both groundwater (aquifers) and surface water. Figure 8 shows the different types of aquifers in the New England area. The recharge of aquifers is essential in the Long Island Sound Basin. For example, Nassau and Suffolk counties are dependent on aquifers for freshwater water supply. However, the extensive development on Long Island hinders the aquifer's ability to recharge.[42] The less permeable surfaces obstruct the flow of water. Additionally, water consumption outpaces the recharge rate. This could lead to saltwater intrusion into the aquifer, which could render the water supply undrinkable.

Valuation Method

Water regulation is highly amenable to different types of economic valuation. The cost of replacing water regulation, like a storage facility, is one way. Economist have also conducted surveys asking households what they were willing to pay to preserve natural stream-flow in rivers.[44]

FIGURE 8 | AQUIFERS IN NEW ENGLAND



Source: U.S. Geological Survey[43]

Key
- Early Mesozoic Basin Aquifer
- New York and New England Carbonate-Rock Aquifer
- Northern Atlantic Coastal Plain Aquifer System
- Aquifers of Alluvial and Glacial Origin

Nassau and Suffolk counties are dependent on aquifers for freshwater water supply.

SUPPORTING SERVICES

Habitat and Nursery

Description

A healthy ecosystem provides physical structure, adequate food availability, appropriate chemical and temperature regimes, and protection from predators to the organisms it sustains. These structural and functional characteristics of an ecosystem are encapsulated in the service of habitat and nursery.

Habitat is the biophysical space formed by, typically natural, processes in which species form their niches and meet their needs. Nurseries refer more specifically to spaces that enable reproduction or breeding grounds for desirable species. These services are generally classified as supporting services because they ensure the existence of the many other species and ecosystem functions valued by humans.

Local Reference

The Long Island Sound has a number of coastal habitats that are highly productive and critical for maintaining ecosystem services. For example, estuaries in the inlets of the Sound host much foraging and breeding wildlife, such as scallops and finfish.[45] Aquatic grass beds, such as eelgrass, provide refuge for juvenile fish and lobsters while improving water quality. Tidal wetlands are also important refuges that also trap sediments, store flood water, and reduce wave energy during storms. A number of other important habitats can be found in forests and grasslands, providing breeding grounds for terrestrial and avian species that are valued for themselves or for their contribution to general ecosystem productivity.

Valuation Method

By sustaining activities like commercial and recreational fisheries or by providing recreational opportunities to bird watchers and game hunters, habitats and nurseries enable much valuable economic activity to take place. Their value can be calculated in similar ways to how factors of production are priced when valuing a firm or industry, for example, since they are production houses ensuring the survival of many species.

Genetic Resources

Description

Genetic information is used for plant improvement, biotechnology, and crop and livestock resistance to pathogens. Meanwhile, although controversial, genetic information has been patented for advances in medical and agricultural biotechnology.

Local Reference

Genetic diversity can bring color to cultivated products such as carrots, a common crop in New England. A total of 75 acres of carrots were harvested in 2012 in counties that overlap with the Long Island Sound Basin.[46] Breeders have produced carrots in a variety of different colors, appealing to a wide market. Similar to other ecosystem services, this service is dependent upon human input.

Valuation Method

Genetic resources are difficult to measure because of the low amenability to economic valuation. As with other public goods, measuring the value of genetic resources is difficult because they are seldom traded in markets. Even when markets for crop varieties exist, markets for germplasm resources do not exist.[47]

The Long Island Sound hosts much foraging and breeding wildlife.

INFORMATION SERVICES

Aesthetic Information

Description

Many features of ecosystems provide opportunities for aesthetic enjoyment, such as a spectacular view, the scents of a flowering meadow or hedgerow, or the sound of the surf. Aesthetic appreciation of nature is one of the most fundamental ways people relate to their physical environment. The existence of vacation homes, parks, scenic areas, and nature travel demonstrates the importance of this ecosystem service. People are willing to pay more for real estate located near environmental amenities, a truth quantitatively reflected in the real estate market.

Local Reference

In Fairfield, Connecticut, 3.3% of median housing price is attributed to properties adjacent to open fields.[48] The highest-valued natural amenities are lakes and ponds, representing 8.7% of the median housing price.

Valuation Method

The value of aesthetic views is implied by what people will be willing to pay for the view through purchases in housing markets.

Cultural and Artistic Inspiration

Description

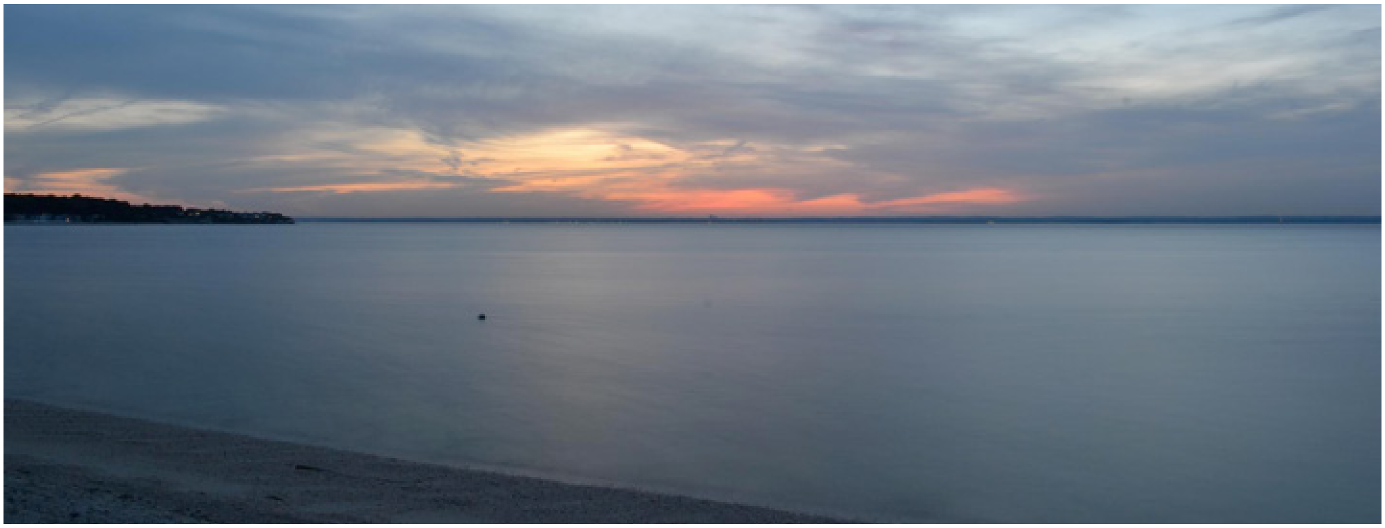
Cultural and artistic inspiration uses nature as motifs in art, film, folklore, books, cultural symbols, architecture, and media.

Local Reference

The natural capital of New England is interwoven into the collective heart and soul of the region and of the nation's history. Natural assets have provided a rich flow of inspiration to the arts. The Hudson River School was noted as America's first "artistic fraternity" and Herman Melville's Moby Dick, published in 1851, is considered by many critics to be the first "great American novel." Today, the character and economy of many New England towns are both supported by landscape art galleries, outdoor theaters, and cultural landmarks based in nature. The turning of the seasons provides constant inspiration to those living in the Northeast.

Valuation Method

Cultural and artistic inspiration is not amenable to economic valuation. Surveys are an appropriate method.



Aesthetic appreciation of nature is one of the most fundamental ways people relate to their physical environment.

Recreation and Tourism

Description

Ecosystems can provide a wide range of leisure opportunities such as tourism, fishing, hiking and other outdoor recreational activities.

Local Reference

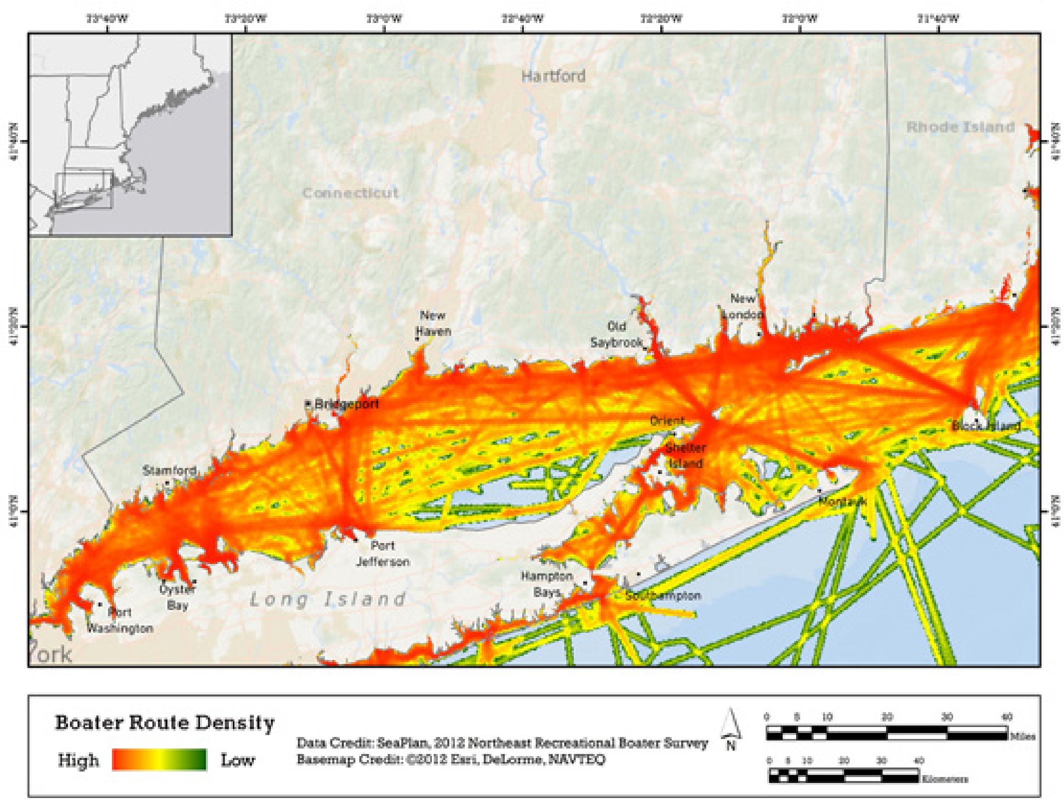
The Long Island Sound Basin provides an incredible diversity of recreational activities. The basin contains 921,000 acres[49] of protected areas where people can enjoy activities from hiking to skiing. The north shore of Long Island opens to the North Fork, which is a quiet and natural alternative to the busy beach towns of Long Island's South shore. Connecticut's Shoreline Gateway Trail is a 25-mile continuous path frequented by bikers, walkers, and hikers.[50] Mount Greylock State Reservation is another popular hiking destination in the Basin and is also Massachusetts' first state park.[51] Popular ski areas include Stowe, Bromely, Magic Mountain, and Jiminy Peak.

The study area includes marinas, rivers, inlets, and open water which provide opportunities for recreation. Several rivers in Connecticut are popular for canoeing, kayaking, tubing, and white-water rafting.[52] Recreational boaters heavily use the Sound during the boating season. Figure 9 shows popular boating routes in the Sound.

Valuation Method

Variations in visitor travel costs and number of trips taken trace out a demand curve for recreation at a particular site. Surveys that ask what people are willing to pay for an activity are another acceptable method.

FIGURE 9 | LONG ISLAND SOUND RECREATIONAL BOATING TRAFFIC



Source: Starbuck et al. 2013[53]

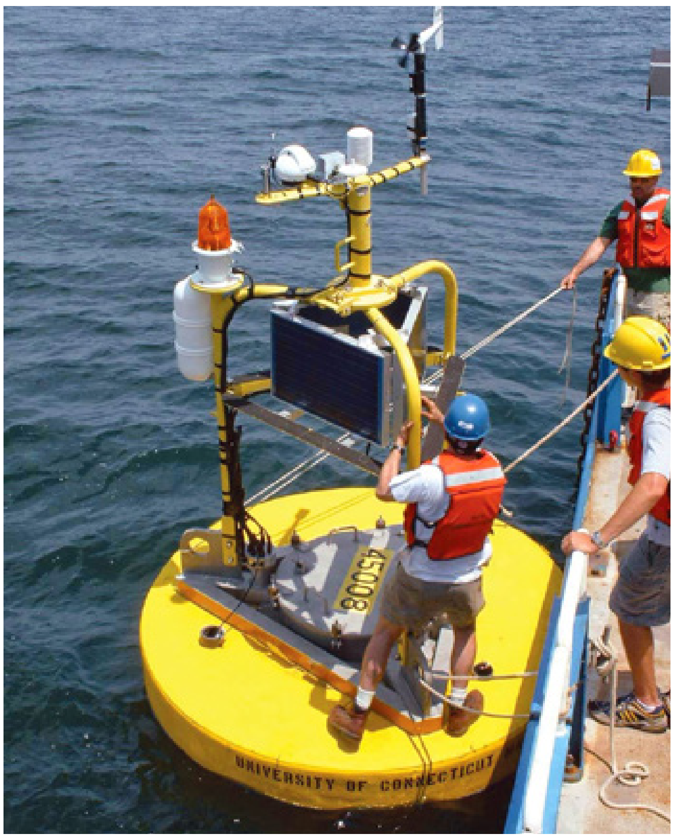
Science and Education

Description

Natural systems provide the opportunity for education and scientific research.

Local Reference

Many opportunities for scientific research in the Long Island Sound exist and the Long Island Sound Study supports research and monitoring programs. For example, the Long Island Sound Study Research Grant Program, a cooperative program developed by the Connecticut and New York Sea Grant programs and the EPA Long Island Sound Office, provides funding for scientists whose work supports the goals and management needs of the Long Island Sound Study.



The Long Island Sound Study supports many research and monitoring programs.

Additionally, surveys to map the sea floor of the Sound were initiated in 2012, funded by a $6 million dollar contribution to the Long Island Sound Research and Restoration Fund in 2004. This project will increase knowledge of seafloor habitats in Long Island Sound and the information gained will support infrastructure planning, species and habitat identification, and general mapping and ocean management.

Valuation Method

Looking at market prices, the dollar value of grants is one acceptable method in assessing nature's science and education value.

Spiritual and Historical

Description

Natural lands often have special significance to groups of people through religious and spiritual purposes or historical importance.

Local Reference

National, state, county, and city historical sites and landmarks in the Northeast like Mystic Seaport Connecticut, Mashantucket Pequot Reservation Archaeological District, and Putnam Memorial State Park often either implicitly contain protected land or attract visitors to connect to the natural landscape through history.

Valuation Method

There are limitations in applying economic valuation to spiritual values. Alternatively, there are non-monetary ranking exercises that value spiritual and historical services.

ESTIMATING NATURE'S VALUE IN LONG ISLAND SOUND AND ITS BASIN

MONETIZING ECOSYSTEM GOODS AND SERVICES

An ecosystem asset produces a flow of valuable services. We can calculate the net present value of an ecosystem as a natural capital asset based on the flows of ecosystem services provided over time, just as we can for a traditional capital asset such as a power plant or a bridge. However, in the case of natural capital, we have to rely on non-market valuation methods to estimate values for the services being provided since many of these do not have market prices. Non-market valuation methods rely on market proxies that reveal a complementary or substitutive relationship with the environmental good or service that in turn allows a value calculation. Alternatively, survey methodologies can be used to ask people's willingness to pay for the environmental good or service in question.

Prices are generally derived at the margin—that is the value of an extra unit of the good or service given the current stock and demand for it. Some of these values may be very high because the good may be scarce, because the evaluating population may have high incomes, or because there are no close substitutes. Similarly, values can be low for opposite reasons. Price derivation through these frameworks, however, requires detailed knowledge and attention to representing ecosystem dynamics accurately—given factors such as the existence of thresholds or non-linear systems.

Thus, this calculation is an estimate of the annual and asset value without a potential for sale. It is useful for revealing the scope and scale of the economic value that these natural watershed systems possess. The values can be seen as a baseline for eventual, specific economic applications.

METHODOLOGICAL APPROACH

Benefit Transfer

Benefit transfer methodology (BTM) was used to estimate the value of the ecosystem services produced by each land cover type in the Long Island Sound Basin. BTM is a federally accepted economic methodology in which the estimated economic value of a good or service is determined by examining previous primary valuation studies of similar goods or services in other comparable locations, with similar environmental and socio-demographic characteristics.[54] BTM is especially useful when the cost of conducting original valuation studies on every site for every vegetation type is infeasible.

The "transfer" refers to the application of derived values and other information from the original study site to a new but sufficiently similar site, analogous to a house or business comparable.[55,56] This appraisal technique has gained popularity in the last several decades because it does not require costly and time consuming primary studies. Instead, BTM can tailor the results from original studies to extract value estimates for different sites, providing approximate values that can be used to inform decision makers and regional planners about the type and magnitude of their natural capital.[57,58]

TABLE 8	VALUATION METHODS USED IN PRIMARY STUDIES
Revealed-Preference Approaches	
Travel Cost	Uses variations in visitor travel costs and number of trips taken to trace out a demand curve for recreation at a particular site. *Example: The value of the recreation ecosystem service as the consumer surplus or the additional amount visitors will pay over and above their costs.*
Hedonic Pricing	The value of a service is implied by what people will be willing to pay for the service through purchases in related markets. *Example: Housing prices along the coastline tend to exceed the prices of inland homes.*
Market-Based Approaches	
Market Pricing	Valuations are directly obtained from what people are willing to pay for the service or good on a private market. *Example: Timber is often sold in a private market.*
Replacement Cost	Cost of replacing ecosystem services with man-made systems. *Example: the cost of replacing a watershed's natural filtration services with a man-made water filtration plant.*
Avoidance Cost	Value of costs avoided or mitigated by ecosystem services that would have been incurred in the absence of those services. *Example: Wetlands buffer the storm surge of a hurricane, reducing damage along the coast.*
Production Approaches	Service values are assigned from the impacts of those services on economic outputs. *Example: Improvement in watershed health leads to an increase in commercial and recreational salmon catch.*
Stated-Preference Approaches	
Contingent Valuation	Value for service demand elicited by posing hypothetical scenarios that involve some valuation of land use alternatives. *Example: People are willing to pay for preservation of wilderness for aesthetic and other reasons.*
Group Valuation	Discourse-based contingent valuation, which is arrived at by bringing together a group of stakeholders to discuss values to depict society's willingness to pay. *Example: Government, citizen's groups, and businesses come together to determine the value of an area and the services it provides.*
Conjoint Analysis	People are asked to choose or rank different service scenarios or ecological conditions that differ in the mix of those conditions. *Example: Choosing between wetlands scenarios with differing levels of flood protection and fishery yields.*

Adapted from Farber et al.

Primary Valuation Methods

Earth Economics maintains, and is continually expanding, an Ecosystem Valuation Toolkit database (EVT) that houses published, peer-reviewed ecosystem service valuation studies for use in benefit transfer studies. Primary studies in the database employ a variety of methods to value ecosystem services. The valuation techniques used to derive the values in the database studies were primarily developed within the disciplines of environmental and natural resource economics, but correlate to business and market valuations, and are listed in Table 8. Revealed-preference approaches measure the value of consumptive uses. Market-based approaches use market prices in their analyses. Stated-preference approaches allow consumers to specify their preferences, often through surveys or questionnaires.

Application of Benefit Transfer to the Long Island Sound Basin

The first step in the valuation of the natural capital present in the Long Island Sound Basin was to characterize the land cover of the area based on GIS maps and other biophysical studies of the area. Once the relative sizes and characteristics of the land cover were established, potential ecosystem services present in each area were identified, using the 21 categories of ecosystem services outlined previously. Subsequently, original studies were carefully selected from the Earth Economics database (EVT) to determine their fit with the ecosystems and land cover characteristics of the Long Island Sound Basin. Every study was reviewed for its potential applicability, and only primary studies from the east coast of the United States were included in the analysis. Moreover, only services that could be found in the LIS Basin were retained. The selection process excluded value estimates from ecosystem types with very different ecologies or from areas with very different income demographics to the watershed.

Table 9 provides a matrix that summarizes the suite of ecosystem services existing on each land cover in the Long Island Sound Basin, compared with those actually valued in this study. Fourteen of the 21 ecosystem services were valued across eight land cover types.

Valuation Gaps and Study Limitations

The greatest limitation to this analysis is a lack of primary valuation studies representing all of the ecosystem services provided in the Long Island Sound Basin. Any category not included in the analysis does not mean the ecosystem does not produce that service. It also does not indicate that service is not valuable. Many ecosystem services that clearly have economic value provided by a land cover type could not be assigned value due to lack of data. The lack of available information underscores the need for investment in conducting local primary valuations. The data provided in Table 9 clarifies ecosystem service/land cover data gaps, and can be useful in prioritizing local primary valuations to fill these gaps and further refine ecosystem service values in the region. Appendix A contains greater detail on the limitations of this study.

Interpreting the Valuation Results

Values for ecosystem services can vary due to factors such as scarcity, income effects, and uniqueness of habitat. The values provided include an array of marginal and average values for ecosystem services, which incorporate different potential demand scenarios and states of the environment. By extracting values from a large pool of studies and contexts we are able to integrate general wisdom and different situations to illustrate a well-informed value approximation. The range of values gives insight on potential differences in value that can be expected given different contexts.

In addition, value comparisons between land cover values should be avoided. For example, the lower value per acre of beaches as compared to wetlands primarily reflects the lack of valuation studies for beaches and greater availability of valuation data for wetlands.

TABLE 9	ECOSYSTEM SERVICES VALUED IN THE LONG ISLAND SOUND BASIN								
	Beach	Coastal wetland	Cultivated	Estuary	Forest	Fresh water	Freshwater wetland	Grassland	Seagrass
Provisioning Services									
Energy and Raw Materials					X				
Food	X	X		X					
Water Supply							X		
Regulating Services									
Biological Control			X		X				
Climate Stability		X	X	X	X		X	X	X
Moderation of Extreme Events		X					X		
Pollination			X						
Soil Formation			X						
Waste Treatment		X				X	X		
Supporting Services									
Habitat and Nursery		X		X					X
Information Services									
Aesthetic Information	X	X	X	X	X	X	X	X	
Cultural and Artistic Inspiration	X	X	X	X					X
Recreation and Tourism	X	X		X	X	X	X		
Science and Education					X				

KEY

Ecosystem service exists on this land cover and is valued in this report	X
Ecosystem service exists on this land cover	
Ecosystem service does not exist on this land cover	

The asset value calculated here is based on a snapshot of the current land cover, consumer preferences, population base and productive capacities. When adding together future flows of ecosystem services in order to calculate a net present value, a decision has to be made about future world states. One central methodological question is that of the discount factor. Discounting is designed to reflect the following:

- **Pure time preference of money.** This is the value that people put on something for use now, as opposed to the value they assign for that use or income at a later date.
- **Opportunity cost of investment.** A dollar in one year's time has a present value of less than a dollar today, because a dollar today can be invested for a future positive return.
- **Depreciation.** Built assets such as roads, bridges, and levees deteriorate and lose value due to wear and tear. Eventually, they must be replaced.

Discounting has limitations when applied to natural capital, however. Using a discount rate assumes that the benefits humans reap in the present are more valuable than the benefits provided to future generations, or even to this generation in just a few years into the future. Therefore, it is generally recommended that natural capital assets be treated with lower discount rates (resulting in more future value being accounted for) than built capital assets because they are public goods that provide public benefits. The objective is to maximize social welfare, implying an intergenerational equity principle that would call for future generations to have a productive base at least as productive as the one we have in the present. Natural capital is many times unsubstitutable and relatively scarce compared to other types of capital and hence has a higher opportunity cost. Current externalities, risks, and uncertainties in markets make today's observed consumption sub-optimal and hence observed interest rates or time preferences sub-optimal as well. Incorporating these market imperfections can make the case for using discount rates for environmental services that are close to zero.[59,60]

Moreover, economists like Weitzman have demonstrated that discounted long-term benefits emerging from natural capital can be at a great disadvantage due to compounding effects of discount rates in the long term.[61] Moreover, given that the current population of the LIS is likely to increase in the future and that if managed well, local ecosystems can self-regenerate to continue providing life-sustaining ecosystem services, their value can be expected to increase as more demands are made from existing natural resources. For these important reasons, the net present value of the Long Island Sound Basin was calculated using a low discount rate of 4%[i] over 100 years. Currently there is no unanimous consensus for the use a specific discount rate, but for the reasons stated above, a lower discount rate should be preferred. The cut-off date of 100 years is arbitrary. However, if ecosystems are well-maintained, their productive life can go well beyond the 100-year point.

As the values in our database were published in many different years, all values are standardized to 2012 dollars using the Bureau of Labor Statistics Consumer Price Index Inflation Calculator. More detailed information on the primary studies used in this benefit transfer is listed in Appendices A and C. The values are also converted when possible and necessary to dollars per acre per year. This is a common unit used in valuation studies or in some cases it is relatively easy to convert to this standardized form. Values that could not be converted to this metric were either excluded or presented as stock (one time) values.

i Federal agencies like the Army Corps of Engineers used a 4% discount rate for water resource projects in the year 2012.

RESULTS

The database contains many values for each ecosystem service in each land cover, which are presented in the results as a range from the lowest value to the highest value existing in the database for that combination. In the final calculations, the values for all the services included in each land cover type are aggregated, resulting in a total value range for the land cover category. Values were then summed across all land covers, resulting in a total annual flow, as presented in the tables below.

TABLE 10 LOW AND HIGH DOLLAR PER ACRE ESTIMATES FOR ESTUARY AND BEACH COVER TYPES

	Estuary		Beach	
Ecosystem Service Specific	Low ($/acre/year)	High ($/acre/year)	Low ($/acre/year)	High ($/acre/year)
Food	73	1,990	3,398	7,539
Habitat and Nursery	2	17		
Cultural and Artistic Inspiration	914	914	3,793	6,343
Recreation and Tourism	1,207	1,207	620	620
Climate Stability	25	25		
TOTAL	***2,220***	***4,152***	***7,811***	***14,502***

TABLE 11 LOW AND HIGH DOLLAR PER ACRE ESTIMATES FOR SEAGRASS AND FRESH WATER COVER TYPES

	Seagrass		Fresh Water	
Ecosystem Service Specific	Low ($/acre/year)	High ($/acre/year)	Low ($/acre/year)	High ($/acre/year)
Aesthetic Information			2	2
Waste Treatment			2	2
Habitat and Nursery	1,456	16,670		
Cultural and Artistic Inspiration	8,359	11,399		
Recreation and Tourism			244	20,533
Climate Stability	45	45		
TOTAL	***9,861***	***28,114***	***248***	***20,537***

TABLE 12 LOW AND HIGH DOLLAR PER ACRE ESTIMATES FOR FOREST AND FRESHWATER WETLAND LAND COVER TYPES

	Forest		Freshwater Wetland	
Ecosystem Service Specific	Low ($/acre/year)	High ($/acre/year)	Low ($/acre/year)	High ($/acre/year)
Moderation of Extreme Events			5,971	5,971
Waste Treatment			4,420	4,420
Biological Control	2	11		
Energy and Raw Materials	18	18		
Science and Education	403	403		
Water Supply			18,043	18,043
Recreation and Tourism	527	537	88	10,048
Climate Stability	43	594	9	39
TOTAL	***993***	***1,564***	***28,531***	***38,521***

TABLE 13	LOW AND HIGH DOLLAR PER ACRE ESTIMATES FOR COASTAL WETLAND AND CULTIVATED LAND COVER TYPES			
	Coastal Wetland		Cultivated	
Ecosystem Service Specific	Low ($/acre/year)	High ($/acre/year)	Low ($/acre/year)	High ($/acre/year)
Food	1	698		
Aesthetic Information			29	74
Moderation of Extreme Events	3,800	3,800		
Waste Treatment	1,912	57,530		
Habitat and Nursery	92	462		
Cultural and Artistic Inspiration	5,733	13,591	8,909	17,838
Biological Control			51	51
Pollination			45	1,847
Soil Formation			7	7
Recreation and Tourism	151	994		
Climate Stability	11	186	2	254
TOTAL	***11,699***	***77,260***	***9,042***	***20,071***

TABLE 14	LOW AND HIGH DOLLAR PER ACRE ESTIMATES FOR THE GRASSLAND LAND COVER TYPE	
	Grassland	
Ecosystem Service Specific	Low ($/acre/year)	High ($/acre/year)
Climate Stability	6	27
TOTAL	***6***	***27***

MARGINAL VALUES can many times be much lower than average or total values; therefore their use is likely to result in an underestimation.

TABLE 15	TOTAL ANNUAL VALUE OF ECOSYSTEM SERVICES PRODUCED IN THE LONG ISLAND SOUND BASIN				
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre/year)	High ($/acre/year)	Low ($/year)	High ($/year)
Beach	3,664	7,811	14,502	28,620,797	53,135,219
Coastal Wetland	3,474	11,699	77,260	40,640,487	268,384,931
Cultivated	712,915	9,042	20,071	6,446,130,523	14,308,561,251
Estuary	799,669	2,220	4,152	1,775,534,990	3,320,014,695
Forest	7,152,735	993	1,564	7,099,733,030	11,183,637,314
Fresh Water	254,761	248	20,537	63,177,562	5,231,969,423
Freshwater Wetland	56,791	28,531	38,521	1,620,317,919	2,187,648,842
Grassland	37,072	6	27	221,352	996,085
Seagrass	2,061	9,861	28,114	20,324,564	57,946,623
Total	***9,023,142***			***17,094,701,225***	***36,612,294,384***

THESE VALUES are snapshots based on current land cover. In addition, the per area and total values represent a minimum because not every ecosystem service could be valued on each land cover.

Value organized by Habitat/Land Cover

Table 10 through Table 14 summarize the combined high and low ecosystem service values for each land cover in the Long Island Sound Basin. In the case where high and low values are the same, only one relevant value was found. It is important to note that additional values from future or newly uncovered prior studies may increase or decrease the value range presented. Table 15 presents the total ecosystem service value of land covers in the Long Island Sound Basin. Appendix B provides the annotated bibliography and Appendix C provides a reference table for the values used.

Figure 10 shows the total value of land cover classes in the entire Long Island Sound Basin and the percent of value determined by valuation method.

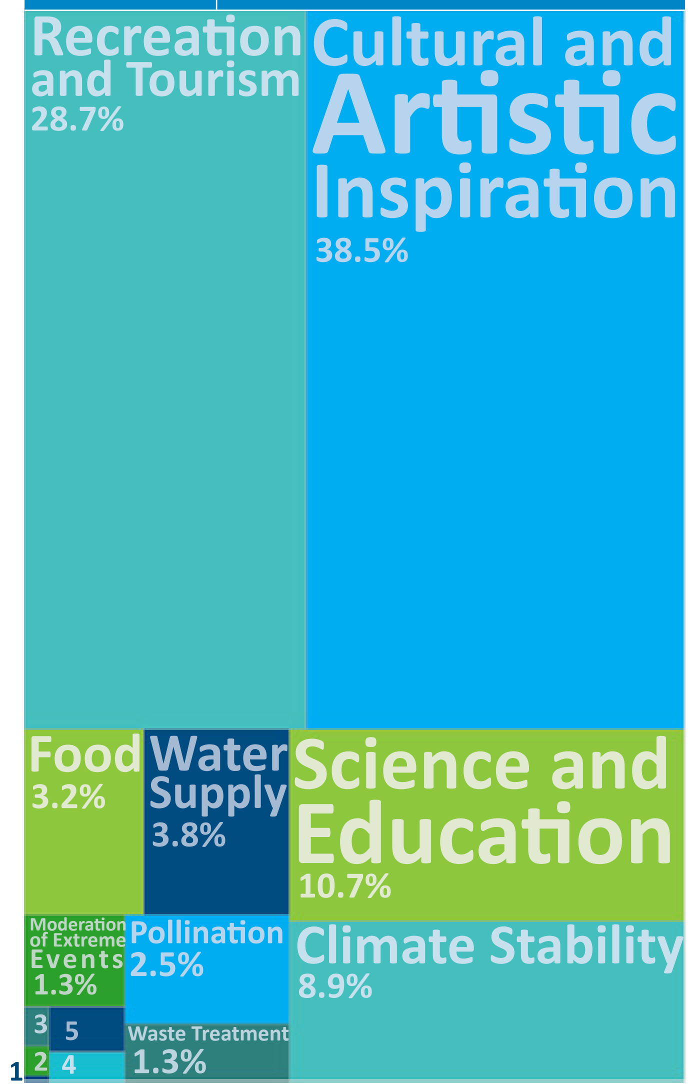
Figure 11 displays the total value of land cover types in the entire Long Island Sound Basin and the relative values for ecosystem service that comprise the total.

DOUBLE COUNTING can be an issue with the benefit transfer approach. However, the risk of undervaluation may be greater.

FIGURE 10 RELATIVE ANNUAL VALUE OF LAND COVER TYPES

<1%: 1 Beach, 2 Coastal Wetland, 3 Seagrass

FIGURE 11 TOTAL VALUE BROKEN DOWN BY ECOSYSTEM SERVICE



<1%: 1 Soil Formation, 2 Habitat and Nursery, 3 Aesthetic Information, 4 Biological Control, 5 Energy and Raw Materials

Asset Value

Treated with a 4% discount rate like a built capital bridge or factory, the value of natural capital in the Long Island Sound Basin is $419 billion to $897 billion (Table 16). Because this valuation does not include all ecosystem goods and services, it is an underestimate. Yet even this conservative estimation demonstrates the sizable asset value of the natural capital of the Long Island Sound Basin.

TABLE 16	NET PRESENT VALUE OF THE LONG ISLAND SOUND BASIN
Low Estimate	**High Estimate**
418,905,636,375	897,184,237,165

Carbon storage is a subcategory of climate stability, referring to the stock of carbon being retained rather than removed from the atmosphere on an annual basis. Because of the characteristic of this service, it was included in the asset value rather than the annualized flow of value. Benefit transfer is still used for carbon storage except values are expressed in total values instead of annual values (Table 17).

Benefit transfer was also used to look at the influence of ecosystems to the Long Island Sound housing market, another non-annual "stock" value (Table 18).

TABLE 17 — CARBON STORAGE IN THE LONG ISLAND SOUND BASIN

		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre)	High ($/acre)	Low ($/year)	High ($/year)
Beach	3,664				
Coastal Wetland	3,474	11,878	12,590	41,262,038	43,733,957
Cultivated	712,915	3,960	4,134	2,822,966,984	2,947,452,258
Estuary	799,669				
Forest	7,152,735	2,294	17,883	16,404,987,339	127,911,917,985
Fresh Water	254,761				
Freshwater Wetland	56,791	4,762	82,401	270,451,581	4,679,671,406
Grassland	37,072	206	347	7,630,040	12,875,692
Seagrass	2,061	3,932	3,932	8,105,039	8,105,039
Total	***9,023,142***			***19,555,403,021***	***135,603,756,338***

TABLE 18 — ECOSYSTEM INFLUENCE ON THE LONG ISLAND SOUND HOUSING MARKET

		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre)	High ($/acre)	Low ($/year)	High ($/year)
Beach	3,664	2,075	5,480	7,603,014	20,078,074
Coastal Wetland	3,474	20,572	20,572	71,463,881	71,463,881
Cultivated	712,915				
Estuary	799,669	25,579	25,579	20,454,888,169	20,454,888,169
Forest	7,152,735	32,232	32,232	230,543,888,737	230,543,888,737
Fresh Water	254,761	72	32,184	18,409,089	8,199,262,726
Freshwater Wetland	56,791	5,856	105,014	332,541,150	5,963,881,351
Grassland	37,072	13,880	13,880	514,551,665	514,551,665
Seagrass	2,061				
Total	***9,023,142***			***251,943,345,705***	***265,768,014,603***

The final asset value for this study combines the net present value of the flow of natural benefits over a 100 year horizon with the two other stock values (Table 19). The asset estimate of the Long Island Sound Basin is $690 billion to $1.3 trillion.

Using GIS technology and historical maps, it is possible to make land use comparisons across time by modeling the value of the “starting principle” of natural capital and then calculating the value of what has been lost for development. To illustrate this, we analyzed the loss of wetlands and forests between 1985 and 2010.

The strongest trend in the study area is that forest and wetlands have slowly been converted to turf grass and impervious surfaces including roads, parking lots, and urban areas. We estimate this loss of natural capital from the lower Long Island Sound Basin alone to be approximately $10.1 billion in 2012 dollars.

TABLE 19	ASSET VALUE (INCLUDING STOCK VALUES) OF THE LONG ISLAND SOUND BASIN	
	Low	**High**
Net Present Value (4%, 100 years)	418,905,636,375	897,184,237,165
Carbon Stock	19,555,403,021	135,603,756,338
Influence to Housing Market	251,943,345,705	265,768,014,603
Total	***690,404,385,101***	***1,298,556,008,106***

CONCLUSION AND RECOMMENDATIONS

CONCLUSION

The Long Island Sound Basin is a tremendously valuable asset. Economically valuable goods and services provided include water supply and quality, food, storm and flood protection, climate stability, waste treatment, wildlife habitat, recreation and tourism, value to private properties, medicinal resources, and more.

Within the basin, 21 categories of economically valuable ecosystem goods and services were identified. Of these, 14 were valued, **showing that the Long Island Sound Basin provides between $17 billion and $37 billion in economic value every year.** This is a wide range because it encompasses the lowest and highest estimates for ecosystem service values in markets and peer reviewed literature. Seven value categories remain unvalued.

If natural benefits are lost, economic costs are incurred. As flood plains are filled, flood risks and damages rise. With climate change, storm damage is larger and the storm-buffering value of natural barrier islands, wetlands, beaches, and other natural protective barriers rises. If ecosystem services are lost, tax districts are established to replace natural flood protection with built infrastructure with a shorter effective lifespan.

These benefits are derived from "natural capital" that is long lasting and self-maintaining, unless actively damaged. It is fundamentally different from traditional economic assets like "built capital," such as buildings, roads, and power plants, which depreciate and require capital and maintenance costs. Though our great grandchildren may not drive the same car we drive today, they may drink water from the same aquifer, consume fish from Long Island Sound, and be protected from storms by coastal wetlands.

Despite these differences, the Long Island Sound and its watershed can be valued analogous to a traditional economic asset. This entails calculating a net present value of the annual stream of benefits provided by the Sound. In this analysis, **the asset value of Long Island Sound and its watershed is estimated to be between $690 billion and $1.3 trillion at a 4% discount rate over 100 years.**

Upgrading large assets can yield large returns. **Understanding the stream of benefits provided, the asset value, and the potential increase in value with restoration investments is key to securing the scale of resources required to restore Long Island Sound.** Restoring and preserving the Long Island Sound Basin is an investment in a highly productive and long-lived asset that produces a vast and diverse flow of benefits across time.

In addition, a pioneering study in natural asset valuation and economic impact of the Sound was published by Dr. Marilyn Altobello in 1992.[64] This was an influential study that calculated both direct benefits received from the Sound (i.e. ecosystem services) and the economic impact of those benefits. As these two types of values reflect different perspectives of natural capital (direct user benefits versus user expenditures), we chose to consider them separately in this report.

In the 1992 report, Altobello's estimate of ecosystem services is $908.7 million per year (2012 USD). As Altobello did not include the entire basin in her report, we can provide a direct comparison using only the beach and estuary land cover types assessed above, totaling $1.8 billion to $3.4 billion. Our analysis shows the value of the Long Island Sound alone to be about twice Altobello's inflation-adjusted estimate. Since that time, valuation of natural capital has expanded in scope, methods, and data capacity. The current benefit transfer methodology encompasses a greater range of services as well, including water quality, climate stability, food, and other benefits. This provides a more complete, more accurate and higher estimate of value for the Long Island Sound. In addition, considering the value of the entire basin as in Table 15 demonstrates the fact that the Sound and its drainage basin are one interconnected system which provides value.

Altobello's economic impact analysis was updated with new methods and data (see Appendix G). We examined fisheries and shellfish landings, sportfishing, boating, and beach swimming for direct expenditures and their multipliers. Our update of these economic values totals $31.1 billion dollars annually, more than three times Altobello's inflation-adjusted estimate of $8.6 billion.

Wise investment in natural assets secures more resilient, less risky, and more sustainable returns in property values, food security, water quantity and quality, storm protection, recreation and tourism, materials, medicinal resources, and other goods and services. **A healthy Basin provides greater ecological and economic resilience and productivity.** Rising productivity, lowered risk, and greater resiliency are ingredients for providing job growth, rising real wages, and a more prosperous economy.

RECOMMENDATIONS

Fill the Gaps

A recommendation for future research of primary ecosystem service valuations is first and foremost to fill in key gaps. The greatest limitation to this analysis is the gaps of primary valuation studies representing all of the ecosystem services provided in the Long Island Sound Basin. Granularity on valuation is lacking for more specific land covers, such as some of LISS's priority habitats: intertidal flats, cliffs and bluffs, and rocky intertidal zones.

Furthermore, the economic valuation of aquifer systems should be evaluated. These underground natural systems provide important water storage and filtration services that are not currently valued.

Recommendation: Fill in key gaps by conducting primary valuations for important ecosystems and services not yet documented.

Return on Investment

Private or public understanding of the rate of return on investments is essential to allocating capital efficiently to generate significant and real returns. Understanding the size of assets, as discussed in Chapter 4, and the relative returns on investments in those assets provides robust information for deciding the scale of and potential returns from investment. By utilizing metrics that incorporate ecosystem services, the true value of investments can be understood. The measurement of Return-on-Investment (ROI) has been proven to be superior to other decision-making tools for ensuring cost-efficiency and the maximization of benefits.[62,63]

An ROI calculation considers both costs and benefits. Costs include fixed costs (such as the purchase of land), variable costs (such as maintenance costs), and environmental costs (impairments to ecosystem services). Benefits include market benefits (e.g., rents, yields, jobs) and public or non-market benefits like ecosystem services. Induced benefits, such as the number of jobs created, can also be taken into account.

In its simplest form, return on investment (ROI) is expressed as follows:

$$ROI = \frac{\text{Gain from Investment - Cost of Investment}}{\text{Cost of Investment}}$$

A return on investment analysis evaluating the cost of each strategy and the corresponding value of the projected natural asset enhancements is a good way to research the range of ecosystem restoration and preservation strategies available to enhance LIS natural asset value.

Recommendation: Conduct return-on-investment analysis for LIS restoration and preservation strategies to inform the Comprehensive Conservation and Management Plan.

Funding Mechanisms

Funding mechanisms refer to creative ways to meet financial needs for protecting and managing community assets (including natural capital). They include market mechanisms designed to obtain a desired value from community assets by providing incentives and disincentives for practices that protect or degrade them while also creating a revenue base to invest in their management. The utility and efficiency of funding mechanisms will become more apparent in coming years as new market opportunities develop for habitat, climate control, temperature, and water quality.

Current funding mechanisms are limited. The people who benefit from many aspects of the Long Island Sound Basin (property values, storm protection, drinking water) do not have a means to pay for investment in asset improvements that directly benefit them. In addition, those who may harm these assets (pollution, blight, impermeable surfaces) do not have a system for paying to mitigate for these damages or repair the natural assets.

Researching the full range of locally appropriate funding mechanisms could provide a sustained, reliable source of investment capital to restore and protect ecosystem services identified in this report.

Recommendation: Develop funding tools to generate the financial resources to sustain investment in Long Island Sound Basin natural asset enhancement strategies.

In conclusion, economies need nature. This is clearly evident in the Long Island Sound Basin. If the Long Island Sound Basin is degraded, economic value, sustainability, and quality of life are all degraded. If effective investment in the health of the Long Island Sound Basin is forthcoming, it is a vast asset that can rise in value and provide a wealth of benefits in perpetuity.

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APPENDIX A: STUDY LIMITATIONS

All valuations are limited since information available in space-time is always imperfect and limited. Though such limitations are noteworthy and can lead to better information in the future, they should not detract from the core finding that ecosystems produce a significant economic value to society. A benefit transfer analysis estimates the economic value of a given ecosystem (e.g., wetlands) from prior studies of that ecosystem type. Like any economic analysis, this methodology has strengths and weaknesses. Some arguments against benefit transfer include:

SUPPLY-SIDE AND DEMAND-SIDE ISSUES

- Every ecosystem is unique; per-acre values derived from another location may be irrelevant to the ecosystems being studied.
- Even within a single ecosystem, the value per acre depends on the size of the ecosystem; in most cases, as the size decreases, the per-acre value is expected to increase and vice versa. (In technical terms, the marginal cost per acre is generally expected to increase as the quantity supplied decreases; a single average value is not the same as a range of marginal values).
- Gathering all the information needed to estimate the specific value for every ecosystem within the study area is not currently feasible. Therefore, the full value of all of the wetlands, forests, pastureland, etc. in a large geographic area cannot yet be ascertained. In technical terms, we have far too few data points to construct a realistic demand curve or estimate a demand function.
- To value all, or a large proportion, of the ecosystems in a large geographic area is questionable in terms of the standard definition of exchange value. We cannot conceive of a transaction in which all or most of a large area's ecosystems would be bought and sold. This emphasizes the point that the value estimates for large areas (as opposed to the unit values per acre) are more comparable to national income account aggregates than the exchange values.[ii] These aggregates (i.e. GDP) routinely impute values to public goods for which no conceivable market transaction is possible. The value of ecosystem services of large geographic areas is comparable to these kinds of aggregates (see below).

Proponents of the above arguments recommend an alternative valuation methodology that amounts to limiting valuation to a single ecosystem in a single location. This method only uses data developed expressly for the unique ecosystem being studied, with no attempt to extrapolate from other ecosystems in other locations. The size and landscape complexity of the Long Island Sound Basin makes this approach to valuation extremely difficult and costly. We know that markets are imperfect and estimations and modeling are essential to financial markets. In crisis or scarcity situations, information is often even more imperfect, but decisiveness is required. Responses to the above critiques can be summarized in the following bullets (See Costanza et al. 1997[iii]; and Howarth and Farber 2002[ii] for more detailed discussion).

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ii Howarth, R., Farber, S. 2002. Accounting for the value of ecosystem services. Ecological Economics 41:421-429.

iii Costanza, R., d'Arge, R., Groot, R.d., Farber, S., Grasso, M., Hannon, B., Naeem, S., Limburg, K., Paruelo, J., O'Neill, R.V., Raskin, R., Sutton, P., Belt, M.v.d., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253-260.

- The use of average values in ecosystem valuation is no more or less justified than their use in other macroeconomic contexts; for instance, the development of economic statistics such as Gross Domestic or Gross State Product. This study's estimate of the aggregate value of the Long Island Sound's watershed ecosystem services is a valid and useful (albeit imperfect, as are all aggregated economic measures) basis for assessing and comparing these services with conventional economic goods and services. While every wetland, forest or other ecosystem is unique in some way, ecosystems of a given type, by their definition, have many things in common.

- As employed here, the prior studies upon which we based our calculations encompass a wide variety of time periods, geographic areas, investigators and analytic methods. Many of them provide a range of estimated values rather than single-point estimates. The present study preserves this variance; no studies were removed from the database because their estimated values were deemed to be "too high" or "too low." Also, only limited sensitivity analyses were performed. This approach is similar to determining an asking price for a piece of land based on the prices of comparable parcels ("comps"): even though the property being sold is unique, realtors and lenders feel justified in following this procedure to the extent of publicizing a single asking price rather than a price range.
- The objection to the absence of even an imaginary exchange transaction was made in response to the study by Costanza et al. (1997)[iii] of the value of all of the world's ecosystems. Leaving that debate aside, one can conceive of an exchange transaction in which, for example, all of, or a large portion of a watershed was sold for development, so that the basic technical requirement of an economic value reflecting the exchange value could be satisfied. Even this is not necessary if one recognizes the different purpose of valuation at this scale—a purpose that is more analogous to national income accounting than to estimating exchange values.

In this report, we have displayed our study results in a way that allows one to appreciate the range of values and their distribution. It is clear from inspection of the tables that the final estimates are not precise. However, they are much better estimates than the alternative of assuming that ecosystem services have zero value, or, alternatively, of assuming they have infinite value. We know intuitively and logically that considering no economic value for natural capital is a false premise.

The estimated value of the world's ecosystems presented in Costanza et al. (1997), has been criticized as both (1) a serious underestimate of infinity and (2) impossibly exceeding the entire Gross World Product. These objections seem to be difficult to reconcile, but that may not be so.

Upon some reflection, it should not be surprising that the value ecosystems provide to people exceeds the gross world product. Costanza's estimate of the work that ecosystems do is obviously an underestimate of the "infinite" value of priceless systems, but that is not what he sought to estimate. Consider the value of one ecosystem service, such as photosynthesis, and the ecosystem good it produces: atmospheric oxygen. Neither is valued in Costanza's study. Given the choice between breathable air and possessions, the choice is clear. This indicates that the value of photosynthesis and atmospheric oxygen to people exceeds the value of the gross world product—and oxygen production is only 1 of the 21 ecosystem goods and services.

GENERAL LIMITATIONS

- **Static Analysis.** This analysis is a static, partial equilibrium framework that ignores interdependencies and dynamics, though new dynamic GIS-based data models are being developed. The effect of this omission on valuations is difficult to assess, but value would likely increase given that systems are greater than the sum of their parts.

- **Increases in Scarcity.** The valuations probably underestimate shifts in the relevant demand curves as the sources of ecosystem services become more limited. The values of many ecological services rapidly increase as they become increasingly scarce; this is known among economists as price inelasticity, since regardless of price, substitutes for biotic processes are not readily available (in fact they have not yet been found elsewhere in the Universe).[iv] If ecosystem services are scarcer than assumed here, their value has been underestimated in this study. Such reductions in supply appear likely as land conversion and development have steadily proceeded over the past few decades; climate change may also adversely affect the ecosystems, although the precise impacts are difficult to predict.

- **Existence Value.** The approach does not fully include the infrastructure or existence value of ecosystems. It is well known that people value the existence of certain ecosystems, even if they never plan to use or benefit from them in any direct way. Estimates of existence value are rare, even though flipping through television channels, surfing the Internet, or a perusal through a library will quickly reveal humanity's appreciation for nature around the globe. Aggregate donations made to conserve non-local ecosystems could also be used for existence value.

- **Other Non-Economic Values.** Economic and existence values are not the sole decision-making criteria. A technique called multi-criteria decision analysis is available to formally incorporate economic values with other social and policy concerns (see Janssen and Munda 2002[v] and de Montis et al. 2005[vi] for reviews). Having economic information on ecosystem services usually helps this process because traditionally, only opportunity costs of forgoing development or exploitation are counted against non-quantified environmental concerns. In addition, climate risks are not yet systematically identified and hedged, though some cities and countries are beginning to implement such approaches.

GIS LIMITATIONS

- **GIS Data.** Since this valuation approach involves using benefit transfer methods to assign values to land cover types based, in some cases, on the context of their surroundings, one of the most important issues with GIS quality assurance is reliability of the land cover maps used in the benefits transfer, both in terms of categorical precision and accuracy.
    - *Accuracy:* The source GIS layers are assumed to be accurate but may contain some minor inaccuracies due to land use changes done after the data were sourced, inaccurate satellite readings and other factors.

iv Boumans, R., Costanza, R., Farley, J., Wilson, M., Portela, R., Rotmans, J., Villa, F., Grasso, M. 2002. Modeling the dynamics of the integrated Earth system and the value of global ecosystem services using the GUMBO model. Ecological Economics 41: 529-560.

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vi de Montis, A., de Toro, p., Droste-Franke, B., Omann, I., Stagl, S. 2005. Assessing the quality of different MCDA methods, in M. Getzener, Spash, C., and Stagl, S., (eds.) Alternatives for Environmental Valuation, Routledge, London.

- *Categorical Precision:* The absence of certain GIS layers that matched the land cover classes used in the Earth Economics database created the need for multiple datasets to be combined. For example, a "Coastal wetlands layer" was not obtainable by NLCD, so the US Fish and Wildlife Service's National Wetlands Inventory was used to estimate the acreage of this land cover. This process is likely to produce some inaccuracies in final acreage values for each land cover class and thus affect the final dollar valuation.
- Since beach cover is linked in with the "barren" land cover class, it could only be manually separated through GIS analytic techniques.
- Marine area was also estimated using GIS Analytical techniques since the shoreline is such an irregular, indented, and dynamic land feature.

- **Ecosystem Health.** There is the potential that ecosystems identified in the GIS analysis are fully functioning to the point where they are delivering higher values than those assumed in the original primary studies, which would result in an underestimate of current value. On the other hand, if ecosystems are less healthy than those in primary studies, this valuation will overestimate current value. Current developments in the field are modeling "management regimes" and ecosystem health status to provide coefficients to these values.
- **Spatial Effects.** This ecosystem service valuation assumes spatial homogeneity of services within ecosystems, i.e. that every acre of forest produces the same ecosystem services. In ecology, there are decades of research enumerating edge, island, and fragmentation effects. Whether this would increase or decrease valuations depends on the spatial patterns and services involved. Solving this difficulty requires spatial dynamic analysis. More elaborate system dynamic studies of ecosystem services have shown that including interdependencies and dynamics leads to significantly higher values[iv], as changes in ecosystem service levels cascade throughout the economy.

BENEFIT TRANSFER/DATABASE LIMITATIONS

- **Incomplete coverage.** That not all ecosystems have been valued or studied well is perhaps the most serious issue, because it results in a significant underestimate of the value of ecosystem services. More complete coverage would increase the values shown in this report, since no known valuation studies have reported estimated values of zero or less for an ecosystem service. Table 9 illustrates which ecosystem services were identified in the Long Island Sound Basin for each land cover type, and which of those were valued. In addition, land covers have temporal and seasonal fluctuations in services provided such as winter snow melt, spring blooming, or fall decay. As drought regions experience, snowpack is an important land cover providing critical ecosystem services.
- **Selection Bias.** Bias can be introduced in choosing the valuation studies, as in any appraisal methodology. The use of ranges partially mitigates this problem.
- **Consumer Surplus.** Because the benefit transfer method is based on average rather than marginal cost, it cannot provide estimates of consumer surplus. However, this means that valuations based on averages are more likely to underestimate total value.

PRIMARY STUDY LIMITATIONS

- **Willingness-to-pay Limitations.** Most estimates are based on current willingness-to-pay or proxies, which are limited by people's perceptions and knowledge base. Improving people's knowledge base about the contributions of ecosystem services to their welfare would almost certainly increase the values based on willingness-to-pay, as people would realize that ecosystems provided more services than they had previously known.

- **Price Distortions.** Distortions in the current prices used to estimate ecosystem service values are carried through the analysis. These prices do not reflect environmental externalities and are therefore again likely to be underestimates of true values.

- **Non-linear/Threshold Effects.** The valuations assume smooth and/or linear responses to changes in ecosystem quantity with no thresholds or discontinuities. Assuming (as seems likely) that such gaps or jumps in the demand curve would move demand to higher levels than a smooth curve, the presence of thresholds or discontinuities would likely produce higher values for affected services. Further, if a critical threshold is passed, valuation may leave the normal sphere of marginal change and larger-scale social and ethical considerations dominate, such as an endangered species listing. These threshold effects exist in any human or ecological system as we saw with the Financial Crisis.

- **Sustainable Use Levels.** The value estimates are not necessarily based on sustainable use levels. Limiting use to sustainable levels would imply higher values for ecosystem services as the effective supply of such services is reduced.

If the above problems and limitations were addressed, the result would most likely be a narrower range of values and significantly higher values overall. At this point, however, it is impossible to determine more precisely how much the low and high values would change.

vii Limburg, K.E., O'Neil, R.V., Costanza, R., and Farber, S. 2002. Complex systems and valuation. Ecological Economics, 41, 409-420.

APPENDIX B: VALUE TRANSFER STUDIES USED

ANNOTATED BIBLIOGRAPHY OF BENEFIT TRANSFER STUDIES

Anderson, G. D., Edwards, S.F. 1986. Protecting Rhode Island coastal salt ponds - an economic assessment of downzoning. Coastal Zone Management Journal 14, 67-91.

Anderson and Edwards apply contingent valuation and hedonic pricing to coastal amenities in South Kingstown, Rhode Island, to analyze the effect of downzoning. The net present value of swimmable water is found to be $3.1 million. The hedonic model primarily analyzes the aesthetic value of the coastal area, as reflected in the price of houses, while the contingent valuation surveys willingness to pay to avoid degradation in water quality.

Batie, S.S., Wilson, J.R. 1978. Economic values attributable to Virginia's coastal wetlands as inputs in oyster production. Southern Journal of Agricultural Economics July 111-118.

The authors estimate the economic value of Chesapeake Bay oyster production and compare values among Virginia cities. A production function is built for Virginia oyster harvest.

Bell, F. W. 1997. The economic valuation of saltwater marsh supporting marine recreational fishing in the southeastern United States. Ecological Economics 21 243-254.

Wetlands in the Florida are assessed based on the value they add to recreational fishing. A Cobb-Douglas function is applied to estimate the supply for fishing using cross-sectional state-level data. Using a discount rate of 8.125%, the perpetual flow of consumer surplus per acre of wetlands is valued at $6741 and $981 on the East and West Coast of Florida. The values provide an argument for Florida to acquire more coastal land for preservation and development.

Bergstrom, J. C., Dillman, B.L., Stoll, J.R. 1985. Public environmental amenity benefits of private land: the case of prime agricultural land. Southern Journal of Agricultural Economics 7, 139-149.

Contingent valuation is applied to find the value of environmental amenities for areas that would have been agricultural lands in Greenville County, South Carolina. Marginal household benefits were estimated at $0.06 per thousand acres, or $60 per acre.

Costanza, R., Pérez-Maqueo, O., Martinez, M. L., Sutton, P., Anderson, S. J., and Mulder, K. 2008. The value of coastal wetlands for hurricane protection. AMBIO: A Journal of the Human Environment, 374 241–248.

Costanza et. al construct a regression model using 34 major U.S. hurricanes since 1980. The study finds that a loss of 1 hectare of wetlands corresponds to an average increase of $33,000 in storm damage from specific storms. The authors also mapped the annual value of coastal wetlands by state, finding an average value ranging from $250 to $51,000 per hectare per year, with a mean of $8,240 and a median of $3,230. Coastal wetlands for the entire United States give an estimated value of $23.2 billion per year in storm protection services.

Gosselink, J. G., Odum, E.P., Pope, R.M. 1974. The value of the tidal marsh. Center for Wetland Resources, Lousiana State University, Baton Rouge, Lousiana.

Natural tidal marshes are valued for several uses, such as by-product production, oyster aquaculture, and waste assimilation. The annual social value of tidal marshes is estimated to be between $50,000 and $80,000 per acre.

Hayes, K.M., Tyrrell, T.J., Anderson, G. 1992. Estimating the benefits of water quality improvements in the Upper Narragansett Bay. Marine Resource Economics 7, 75-85.

In response to an EPA study that underestimated the benefits of improved water quality in the Upper Narragansett Bay, Rhode Island, this study calculates the non-user benefits of swimming and shellfishing in the same study area. Contingent valuation revealed that aggregate annual benefits for swimmable waters were between $30 million and $60 million, while shelfishable water was worth between $30 million and $70 million.

Kahn, J. R., Buerger, R.B. 1994. Valuation and the consequences of multiple sources of environmental deterioration - the case of the New-York Striped Bass fishery. Journal of Environmental Management 40 257-273.

This study examines two sources of environmental degradation in the New York striped bass fishery: the decline in environmental quality in Chesapeake Bay and the PCB contamination of striped bass from the Hudson River. The estimated loss in economic value from contamination ranges from $2.3 to $7.7 million annually due to Chesapeake Bay contamination, while the loss is $0.745 to $3.7 million for PCB contamination of the Hudson striped bass.

Lynne, G.D., Conroy, P., Prochaska, F.J. 1981. Economic Valuation of Marsh Areas for Marine Production Processes. Journal of Environmental Economics and Management. 8. 175-186.

A bioeconomic model estimated the value of marshes in blue crab production on the Gulf Coast of Florida. The marginal dockside value per acre is estimated at $0.25 to $0.30. Total revenue from the entire blue crab fishery in Florida is $2.2 million in 1975. Total annual flow to the marsh from the blue crab fishery in 1975 was a maximum of $230,452.

Mazzotta, M. 1996. Measuing Public Values and Priorities for Natural Resources: An Application to the Peconic Estuary System. University of Rhode Island.

In a PhD dissertation, Mazzotta attempts to measure values and priorities for protecting and enhancing natural resources in the Peconic Estuary system. A contingent valuation survey allowed residents to value five specific natural resources: farmland, undeveloped land, wetlands, shellfishing areas, and eelgrass. Given a discount rate of 7.625%, ranges of present values for all five natural resources are derived.

Mullen, J. K., Menz, F.C. 1985. The effect of acidification damages on the economic value of the Adirondack Fishery to New-York anglers. American Journal of Agricultural Economics 67 (1), 112-119.

A travel cost model is used to estimate losses in net economic value of the Adirondack recreational fishery resulting from damages caused by acidic deposition. Annual losses to New York resident anglers are estimated to be approximately $1 million per year in 1976 dollars.

Opaluch , J. J., Grigalunas, J. D., Mazzotta, M., Johnston, R. 1999. Recreational and Resource Economic Values for the Peconic Estuary System. Prepared for the Peconic Estuary Program.

This report was designed to fill a gap in knowledge about recreational and resource values. Four valuation studies included in the report estimate outdoor recreational uses and other resource values provided by the natural assets of the Peconic Estuary System. A hedonic analysis demonstrates that a hypothetical parcel of open space approximately 10 acres in area contributes $410,907 to adjoining property values. Improvements of water quality by 10% brings in $1.3 million in benefits, according to the contingent valuation study focusing on recreation. The study on primary productivity valued several types of wetlands, in addition to restored wetlands. Another contingent valuation study measured resource preferences of the local populace for several land cover types.

Oster, S. 1977. Survey Results on the Benefits of Water Pollution Abatement in the Merrimack River Basin. Water Resources Research 13 (6), 882-884.

The author surveyed individuals' willingness to pay for water pollution abatement in the Merrimack River Basin in New England. With 200 respondents, the mean willingness to pay for pollution abatement was found to be $12.00 per year per person. Home ownership, income, and family size were correlated with willingness to pay.

Pimentel, D. 1998. Benefits of biological diversity in the state of Maryland. Cornell University, College of Agricultural and Life Sciences. Ithaca, New York.

Pimentel estimates the annual economic and environmental benefits of biodiversity in Maryland for several ecosystem services including soil formation, pollination, recreation, and waste treatment. Total annual benefits of ecosystem services in the state of Maryland equal approximately $1.9 billion.

Prince, R., Ahmed, E. 1989. Estimating individual recreation benefits under congestion and uncertainty. Journal of Leisure Research 21, 61-76.

The authors develop an appropriate method to analyze consumer decision making under uncertainty of congestion at recreational sites. They argue that a recursive system is the most appropriate method.

Ribaudo, M., Epp, D.J. 1984. The importance of sample discrimination in using the travel cost method to estimate the benefits of improved water quality. Land Economics 60, 397-403.

The authors identify several methodological issues associated with the travel cost method. Specifically, most travel cost analyses do not account for changes in recreational behavior due to site quality and availability of substitutes. The authors account for these dynamic factors are by using contingent behavior analysis of current and former users at St. Albans Bay in Vermont. Improved water quality appears to be desirable for recreationists.

Shafer, E. L., Carline, R., Guldin, R.W., Cordell, H.K. 1993. Economic amenity values of wildlife - 6 case-studies in Pennsylvania. Environmental Management 17, 669-682.

Both travel cost method and contingent valuation are used to evaluate the economic value of six distinct ecotourism activities in Pennsylvania. The six activities were: catch-and-release trout fishing; catch-and-release trout fishing with fly-fishing equipment; waterfowl viewing; elk viewing; observing migration flights of raptors; and viewing live wildlife in an environmental education setting. The estimated consumer surplus was twice the out-of-pocket payments spent to visit the sites.

Thibodeau, F. R., Ostro, B.D. 1981. An economic analysis of wetland protection. Journal of Environmental Management 19: 72-79.

In response to several policies that offer payments for wetland preservation, this paper quantifies the economic benefits of wetlands in the Charles River Basin in Massachusetts. The paper also analyzes the legal issues associated with wetland preservation. Benefits assessed included water regulation, aesthetic value, waste treatment, water supply, and recreation. These benefits ranged from $188/acre/year for recreation all the way to $6,044/acre/year for water supply.

Winfree, R., Gross, B., Kremen, C. 2011. Valuing pollination services to agriculture. Ecological Economics 71, 80-88.

The authors attempt to apply two existing valuation methods to pollination services, as well as develop a new one. They demonstrate all three methods using a data set on watermelon pollination by native bees and honey bees in New Jersey and Pennsylvania. Some discussion is devoted to explaining why different methods produce disparate values.

Young, C.E., Shortle, J.S. 1989. Benefits and costs of agricultural nonpoint-source pollution controls: the case of St. Albans Bay. Journal of Soil and Water Conservation 44, 64-67.

A cost-benefit analysis is conducted for a combined program to control agricultural runoff and upgrade municipal wastewater treatment in the St. Albans Bay watershed of Lake Champlain in Vermont. Benefits are estimated to exceed costs by $1.7 million for the period 1981 to 2030. Benefits were calculated using appreciation in property values and enhanced recreational experiences.

ANNOTATED BIBLIOGRAPHY OF HEDONIC ANALYSIS STUDIES USED

Earnhart, D. 2001. Combining Revealed and Stated Preference Methods to Value Environmental Amenities at Residential Locations. Land Economics 77(1): 12-29.

A combined approach is developed to value the aesthetic benefits generated by environmental amenities. The discrete-choise hedonic valuation (revealed) and choice-based conjoint analysis (stated) are applied to the housing market in Fairfield, Connecticut to value seven different environmental amenities. Values for the revealed approach range from -32,412 for disturbed marshes to 45,871 for the restored marsh. Values for the stated approach ranged from 192,985 for open fields to 612,196 for lakes and ponds. The values from the combined model range from a high for lakes and ponds at $21,308, to open fields at a low of $8,032. The authors suggest using the combined model of stated and revealed approaches.

Pompe, J., Rinehart, J.R. 1995. Beach quality and the enhancement of recreational property-values. Journal of Leisure Research 27 143-154.

The hedonic method is used to find the effect of beach quality on property values in two South Carolina towns. Beach width is used as a proxy measurement for beach quality. Marginal values for beach width vary along the supply curve: additional beach width is worth more for slimmer beaches, relative to the same addition to an already wide beach.

Rich, P.R., Moffitt, L.J. 1982. Benefits of pollution control on Massachusetts' Housatonic River: A hedonic pricing approach. Water Resources Bulletin 18 (6): 1033-1037.

Using hedonic pricing, the authors value the regional benefits of a pollution abatement program instituted for point source pollution along the Housatonic River during the 1960s. Benefits for riparian and nonriparian land are given.

Thibodeau, F. R., Ostro, B.D. 1981. An economic analysis of wetland protection. Journal of Environmental Management 19: 72-79.

In response to several policies that offer payments for wetland preservation, this paper quantifies the economic benefits of wetlands in the Charles River Basin in Massachusetts. The paper also analyzes the legal issues associated with wetland preservation. Aesthetic benefits were assessed using the hedonic pricing method. These benefits range from $12 per acre per year to $39 per acre per year.

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Aalde, H., Gonzalez, P., Gytarsky, M., Krug, T., Kurz, W.A., Ogle, S., Raison, J., Schoene, D., Ravindranath, N.H., Elhassan, N.G., Heath, L.S., Higuchi, N., Kainja, S., Matsumoto, M., Sanchez, M., Somogyi, Z. 2006. Chapter 4: Forest land. In 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 4 Agriculture, Forestry, and other land use.

Bridgeham, S.D., Megonigal, J.P., Keller, J.K., Bliss, N.B., Trettin, C. 2006. The carbon balance of North American wetlands. Wetlands 26(4): 889-916.

Chmura, C., Anisfeld, S.C., Cahoon, D.R., Lynch, J.C. 2003. Global carbon sequestration in tidal, saline wetland soils. Global biogeochemical cycles 17(4).

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APPENDIX C: VALUE REFERENCE TABLES

BENEFIT-TRANSFER ECOSYSTEM SERVICES VALUE REFERENCE TABLE				
Land Cover	**Ecosystem Service**	**Author(s)**	**Low ($/acre/year)**	**High ($/acre/year)**
Coastal Wetland	Cultural and Artistic Inspiration	Mazzotta	5,733	13,591
		Opaluch et al.	6,772	9,135
	Food	Batie and Wilson	6	698
		Lynne et al.	1	1
	Habitat and Nursery	Opaluch et al.	92	462
	Moderation of Extreme Events	Costanza et al.	3,800	3,800
	Recreation and Tourism	Anderson and Edwards	360	360
		Bell	151	994
	Waste Treatment	Gosselink et al.	1,912	57,530
Cultivated	Aesthetic Information	Bergstrom et al.	29	74
	Biological Control	Pimentel	51	51
	Cultural and Artistic Inspiration	Mazzotta	9,556	17,838
		Opaluch et al.	8,909	13,896
	Pollination	Pimentel	95	95
		Winfree	45	1,847
	Soil Formation	Pimentel	7	7
Estuary	Cultural and Artistic Inspiration	Earth Economics*	914	914
	Food	Hayes et al.	1,041	1,990
		Earth Economics*	73	73
	Habitat and Nursery	Kahn and Buerger	2	17
	Recreation and Tourism	Earth Economics*	243	964
Forest	Biological Control	Pimentel	2	11
	Energy and Raw Materials	Pimentel	18	18
	Recreation and Tourism	Prince and Ahmed	36	46
		Shafer et al.	3	489
	Science and Education	Shafer et al.	403	403
Fresh Water	Aesthetic Information	Young and Shortle	2	2
	Recreation and Tourism	Mullen and Menz	237	340
		Oster	5,147	5,147
		Ribaudo and Epp	643	643
		Shafer et al.	4,028	15,386
		Young and Shortle	7	7
	Waste Treatment	Young and Shortle	2	2

BENEFIT-TRANSFER ECOSYSTEM SERVICES VALUE REFERENCE TABLE

Land Cover	Ecosystem Service	Author(s)	Low ($/acre/year)	High ($/acre/year)
Freshwater Wetland	Moderation of Extreme Events	Thibodeau et al.	5,971	5,971
	Recreation and Tourism	Shafer et al.	88	88
		Thibodeau et al.	560	10,048
	Waste Treatment	Thibodeau et al.	4,420	4,420
	Water Supply	Thibodeau et al.	18,043	18,043
Seagrass	Cultural and Artistic Inspiration	Opaluch et al.	8,359	11,399
	Habitat and Nursery	Mazzotta	6,795	16,670
		Opaluch et al.	1,456	1,456
Beach	Cultural and Artistic Inspiration	Opaluch et al.	3,793	6,343
	Food	Mazzotta	3,398	7,539
	Recreation and Tourism	Earth Economics*	620	620

*In-house calculation by Earth Economics. See Appendix G for more details.

CARBON SEQUESTRATION REFERENCE TABLE

Land Cover	Author(s)	Min ($/acre/year)	Max ($/acre/year)
Seagrass	Duarte et al	45	45
	Laffoley and Grimsditch (eds)	45	45
Coastal Wetland	Bridgeham et al	120	140
	Chmura et al	11	186
	Duarte et al	83	83
	Laffoley and Grimsditch (eds)	115	115
Cultivated	ECCP	30	254
	Lasco et al	115	115
	Manley et al	5	13
	Post and Kwon	2	60
	Schuman et al	5	33
Forest	Goulden et al	77	153
	Heath et al	43	99
	Mates and Reyes	68	70
	Smith et al	67	594
Grassland	ECCP	6	27
Inland Wetland	Bridgeham et al	9	39
Estuary	Duarte et al	25	25

CARBON STORAGE REFERENCE TABLE

Land Cover	Author(s)	Min ($/acre)*	Max ($/acre)*
Seagrass	Laffoley and Grimsditch (eds)	3,932	3,932
Coastal Wetland	Bridgeham et al	11,878	12,590
Cultivated	Manley et al	511	686
	Verchot et al	3,449	3,449
Forest	Heath et al	5,715	16,930
	Mates and Reyes	10,467	13,044
	Smith et al	2,294	17,883
Grassland	Verchot et al	206	347
Inland Wetland	Aalde et al	4,762	4,817
	Bridgeham et al	8,948	82,401

*based on the Interagency Working Group on Social Cost of Carbon (see Appendix B)

HEDONIC ANALYSIS REFERENCE TABLE

Land Cover	Author(s)	Min ($/acre)	Max ($/acre)
Beach	Pompe and Rinehart	2,075	5,480
Coastal Wetland	Earnhart	20,572	20,572
Estuary	Earnhart	25,579	25,579
Forest	Earnhart	32,232	32,232
Fresh Water	Earnhart	32,184	32,184
	Rich and Moffitt	72	86
Freshwater Wetland	Thibodeau	5,856	105,014
Grassland	Earnhart	13,880	13,880

APPENDIX D: SUBWATERSHED VALUES

ANNUAL ECOSYSTEM SERVICE VALUES BY SUBWATERSHED

LOWER CONNECTICUT					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre/year)	High ($/acre/year)	Low ($/year)	High ($/year)
Beach	79	7,811	14,502	618,972	1,149,136
Coastal Wetland	407	11,699	77,260	4,761,900	31,447,020
Cultivated	79,408	9,042	20,071	718,001,828	1,593,758,162
Forest	590,271	993	1,564	585,897,522	922,917,152
Fresh Water	31,922	248	20,537	7,916,160	655,566,746
Freshwater Wetland	11,057	28,531	38,521	315,474,577	425,933,445
Grassland	2,349	6	27	14,024	63,107
Total	***715,493***			***1,632,684,983***	***3,630,834,768***

UPPER CONNECTICUT					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre/year)	High ($/acre/year)	Low ($/year)	High ($/year)
Beach	-	7,811	14,502	-	-
Coastal Wetland	-	11,699	77,260	-	-
Cultivated	388,155	9,042	20,071	3,509,676,605	7,790,475,618
Forest	4,786,329	993	1,564	4,750,862,243	7,483,650,445
Fresh Water	114,019	248	20,537	28,275,334	2,341,585,799
Freshwater Wetland	24,308	28,531	38,521	693,534,170	936,365,146
Grassland	24,912	6	27	148,746	669,359
Total	***5,337,724***			***8,982,497,098***	***18,552,746,367***

HOUSATONIC					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre/year)	High ($/acre/year)	Low ($/year)	High ($/year)
Beach	76	7,811	14,502	589,757	1,094,899
Coastal Wetland	53	11,699	77,260	622,529	4,111,109
Cultivated	139,826	9,042	20,071	1,264,298,868	2,806,380,933
Forest	803,645	993	1,564	797,689,480	1,256,535,956
Fresh Water	30,245	248	20,537	7,500,266	621,125,011
Freshwater Wetland	8,523	28,531	38,521	243,164,533	328,305,084
Grassland	3,132	6	27	18,699	84,146
Total	***985,498***			***2,313,884,133***	***5,017,637,137***

NEW YORK					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre/year)	High ($/acre/year)	Low ($/year)	High ($/year)
Beach	2,258	7,811	14,502	17,634,200	32,738,329
Coastal Wetland	1,620	11,699	77,260	18,950,318	125,145,639
Cultivated	3,924	9,042	20,071	35,481,929	78,759,709
Forest	46,701	993	1,564	46,355,008	73,019,308
Fresh Water	41,316	248	20,537	10,245,740	848,487,959
Freshwater Wetland	649	28,531	38,521	18,518,969	25,003,118
Grassland	1,343	6	27	8,022	36,098
Total	***97,811***			***147,194,185***	***1,183,190,159***

SOUTH CENTRAL COAST					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre/year)	High ($/acre/year)	Low ($/year)	High ($/year)
Beach	537	7,811	14,502	4,194,775	7,787,703
Coastal Wetland	859	11,699	77,260	10,047,431	66,352,033
Cultivated	9,091	9,042	20,071	82,196,619	182,452,924
Forest	146,104	993	1,564	145,021,648	228,440,915
Fresh Water	5,598	248	20,537	1,388,207	114,962,592
Freshwater Wetland	2,433	28,531	38,521	69,418,434	93,724,296
Grassland	1,045	6	27	6,240	28,079
Total	***165,667***			***312,273,353***	***693,748,542***

SOUTHWEST COAST					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre/year)	High ($/acre/year)	Low ($/year)	High ($/year)
Beach	452	7,811	14,502	3,530,185	6,553,875
Coastal Wetland	289	11,699	77,260	3,377,692	22,305,874
Cultivated	5,064	9,042	20,071	45,785,665	101,631,046
Forest	134,793	993	1,564	133,794,478	210,755,660
Fresh Water	5,381	248	20,537	1,334,435	110,509,510
Freshwater Wetland	1,941	28,531	38,521	55,392,188	74,786,962
Grassland	1,081	6	27	6,456	29,053
Total	***149,001***			***243,221,098***	***526,571,979***

Note that these values are snapshots based on current land cover, and represent a minimum because not every ecosystem service could be valued on each land cover.

THAMES					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre/year)	High ($/acre/year)	Low ($/year)	High ($/year)
Beach	263	7,811	14,502	2,050,957	3,807,652
Coastal Wetland	246	11,699	77,260	2,880,618	19,023,257
Cultivated	87,447	9,042	20,071	790,689,009	1,755,102,860
Forest	644,891	993	1,564	640,112,652	1,008,317,877
Fresh Water	26,281	248	20,537	6,517,419	539,731,807
Freshwater Wetland	7,880	28,531	38,521	224,815,049	303,530,792
Grassland	3,210	6	27	19,165	86,244
Total	***770,218***			***1,667,084,869***	***3,629,600,488***

CARBON STORAGE BY SUBWATERSHED

LOWER CONNECTICUT					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre)	High ($/acre)	Low ($)	High ($)
Beach	79			-	-
Coastal Wetland	407	11,878	12,590	4,834,728	5,124,366
Cultivated	79,408	3,960	4,134	314,435,994	328,301,778
Forest	590,271	2,294	17,883	1,353,803,219	10,555,787,870
Fresh Water	31,922			-	-
Freshwater Wetland	11,057	4,762	82,401	52,656,702	911,128,205
Grassland	2,349	206	347	483,400	815,738
Total	***715,493***			***1,726,214,043***	***11,801,157,956***

UPPER CONNECTICUT					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre)	High ($/acre)	Low ($)	High ($)
Beach	-			-	-
Coastal Wetland	-	11,878	12,590	-	-
Cultivated	388,155	3,960	4,134	1,536,999,778	1,604,777,346
Forest	4,786,329	2,294	17,883	10,977,572,623	85,593,627,111
Fresh Water	114,019			-	-
Freshwater Wetland	24,308	4,762	82,401	115,759,636	2,003,009,401
Grassland	24,912	206	347	5,127,308	8,652,333
Total	***5,337,724***			***12,635,459,345***	***89,210,066,191***

HOUSATONIC					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre)	High ($/acre)	Low ($)	High ($)
Beach	76			-	-
Coastal Wetland	53	11,878	12,590	632,050	669,915
Cultivated	139,826	3,960	4,134	553,676,962	578,092,631
Forest	803,645	2,294	17,883	1,843,179,984	14,371,525,079
Fresh Water	30,245			-	-
Freshwater Wetland	8,523	4,762	82,401	40,587,240	702,288,175
Grassland	3,132	206	347	644,564	1,087,702
Total	***985,498***			***2,438,720,800***	***15,653,663,501***

NEW YORK					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre)	High ($/acre)	Low ($)	High ($)
Beach	2,258			-	-
Coastal Wetland	1,620	11,878	12,590	19,240,142	20,392,777
Cultivated	3,924	3,960	4,134	15,538,673	16,223,887
Forest	46,701	2,294	17,883	107,110,128	835,152,239
Fresh Water	41,316			-	-
Freshwater Wetland	649	4,762	82,401	3,091,050	53,484,990
Grassland	1,343	206	347	276,510	466,610
Total	***97,811***			***145,256,503***	***925,720,503***

SOUTH CENTRAL COAST					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre)	High ($/acre)	Low ($)	High ($)
Beach	537			-	-
Coastal Wetland	859	11,878	12,590	10,201,095	10,812,220
Cultivated	9,091	3,960	4,134	35,996,532	37,583,882
Forest	146,104	2,294	17,883	335,094,050	2,612,773,890
Fresh Water	5,598			-	-
Freshwater Wetland	2,433	4,762	82,401	11,586,816	200,488,717
Grassland	1,045	206	347	215,083	362,953
Total	***165,667***			***393,093,575***	***2,862,021,663***

SOUTHWEST COAST					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre)	High ($/acre)	Low ($)	High ($)
Beach	452			-	-
Coastal Wetland	289	11,878	12,590	3,429,350	3,634,795
Cultivated	5,064	3,960	4,134	20,051,009	20,935,204
Forest	134,793	2,294	17,883	309,152,008	2,410,500,266
Fresh Water	5,381			-	-
Freshwater Wetland	1,941	4,762	82,401	9,245,658	159,979,244
Grassland	1,081	206	347	222,544	375,544
Total	***149,001***			***342,100,569***	***2,595,425,053***

THAMES					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre)	High ($/acre)	Low ($)	High ($)
Beach	263			-	-
Coastal Wetland	246	11,878	12,590	2,924,674	3,099,885
Cultivated	87,447	3,960	4,134	346,268,038	361,537,530
Forest	644,891	2,294	17,883	1,479,075,326	11,532,551,531
Fresh Water	26,281			-	-
Freshwater Wetland	7,880	4,762	82,401	37,524,479	649,292,674
Grassland	3,210	206	347	660,630	1,114,813
Total	***770,218***			***1,866,453,147***	***12,547,596,432***

ECOSYSTEM INFLUENCE ON HOUSING MARKETS PER SUBWATERSHED

LOWER CONNECTICUT					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre)	High ($/acre)	Low ($)	High ($)
Beach	79	2,075	5,480	164,428	434,221
Coastal Wetland	407	20,572	20,572	8,373,518	8,373,518
Cultivated	79,408			-	-
Forest	590,271	32,232	32,232	19,025,376,388	19,025,376,388
Fresh Water	31,922	72	32,184	2,306,662	1,027,369,151
Freshwater Wetland	11,057	5,856	105,014	64,745,491	1,161,162,833
Grassland	2,349	13,880	13,880	32,599,343	32,599,343
Total	***715,493***			***19,133,565,830***	***21,255,315,454***

UPPER CONNECTICUT					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre)	High ($/acre)	Low ($)	High ($)
Beach	-	2,075	5,480	-	-
Coastal Wetland	-	20,572	20,572	-	-
Cultivated	388,155			-	-
Forest	4,786,329	32,232	32,232	154,270,907,325	154,270,907,325
Fresh Water	114,019	72	32,184	8,239,051	3,669,608,060
Freshwater Wetland	24,308	5,856	105,014	142,335,432	2,552,681,455
Grassland	24,912	13,880	13,880	345,773,434	345,773,434
Total	***5,337,724***			***154,767,255,242***	***160,838,970,274***

HOUSATONIC					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre)	High ($/acre)	Low ($)	High ($)
Beach	76	2,075	5,480	156,667	413,727
Coastal Wetland	53	20,572	20,572	1,094,681	1,094,681
Cultivated	139,826			-	-
Forest	803,645	32,232	32,232	25,902,725,337	25,902,725,337
Fresh Water	30,245	72	32,184	2,185,476	973,393,906
Freshwater Wetland	8,523	5,856	105,014	49,905,153	895,012,274
Grassland	3,132	13,880	13,880	43,467,849	43,467,849
Total	***985,498***			***25,999,535,162***	***27,816,107,773***

NEW YORK					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre)	High ($/acre)	Low ($)	High ($)
Beach	2,258	2,075	5,480	4,684,463	12,370,751
Coastal Wetland	1,620	20,572	20,572	33,323,008	33,323,008
Cultivated	3,924			-	-
Forest	46,701	32,232	32,232	1,505,248,673	1,505,248,673
Fresh Water	41,316	72	32,184	2,985,471	1,329,704,961
Freshwater Wetland	649	5,856	105,014	3,800,686	68,162,507
Grassland	1,343	13,880	13,880	18,647,158	18,647,158
Total	***97,811***			***1,568,689,457***	***2,967,457,058***

SOUTH CENTRAL COAST					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre)	High ($/acre)	Low ($)	High ($)
Beach	537	2,075	5,480	1,114,327	2,942,720
Coastal Wetland	859	20,572	20,572	17,667,809	17,667,809
Cultivated	9,091			-	-
Forest	146,104	32,232	32,232	4,709,170,674	4,709,170,674
Fresh Water	5,598	72	32,184	404,505	180,163,227
Freshwater Wetland	2,433	5,856	105,014	14,246,887	255,507,453
Grassland	1,045	13,880	13,880	14,504,717	14,504,717
Total	***165,667***			***4,757,108,918***	***5,179,956,599***

SOUTHWEST COAST					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre)	High ($/acre)	Low ($)	High ($)
Beach	452	2,075	5,480	937,781	2,476,497
Coastal Wetland	289	20,572	20,572	5,939,470	5,939,470
Cultivated	5,064			-	-
Forest	134,793	32,232	32,232	4,344,599,892	4,344,599,892
Fresh Water	5,381	72	32,184	388,836	173,184,595
Freshwater Wetland	1,941	5,856	105,014	11,368,252	203,881,245
Grassland	1,081	13,880	13,880	15,007,860	15,007,860
Total	***149,001***			***4,378,242,091***	***4,745,089,558***

THAMES					
		Per-area value		Total Value	
Land Cover	Area (acres)	Low ($/acre)	High ($/acre)	Low ($)	High ($)
Beach	263	2,075	5,480	544,829	1,438,788
Coastal Wetland	246	20,572	20,572	5,065,395	5,065,395
Cultivated	87,447			-	-
Forest	644,891	32,232	32,232	20,785,860,448	20,785,860,448
Fresh Water	26,281	72	32,184	1,899,088	845,838,828
Freshwater Wetland	7,880	5,856	105,014	46,139,251	827,473,584
Grassland	3,210	13,880	13,880	44,551,304	44,551,304
Total	***770,218***			***20,884,060,316***	***22,510,228,348***

NET PRESENT VALUE PER SUBWATERSHED

NET PRESENT VALUE AT A 4% DISCOUNT RATE OVER 100 YEARS		
Subwatershed	**Low ($)**	**High ($)**
Lower Connecticut	40,008,943,865	88,973,602,347
Upper Connecticut	220,116,082,374	454,635,031,123
Housatonic	56,701,728,348	122,957,193,011
New York	3,606,993,361	28,994,073,662
South Central Coast	7,652,258,198	17,000,307,322
South West Coast	5,960,132,760	12,903,645,829
Thames	40,851,913,037	88,943,356,330

TOTAL ASSET VALUE PER SUBWATERSHED

Subwatershed	Low ($)	High ($)
Lower Connecticut	60,868,723,738	122,030,075,757
Upper Connecticut	387,518,796,962	704,684,067,588
Housatonic	85,139,984,310	166,426,964,284
New York	5,320,939,321	32,887,251,223
South Central Coast	12,802,460,691	25,042,285,585
South West Coast	10,680,475,420	20,244,160,440
Thames	63,602,426,500	124,001,181,110

APPENDIX E: JOBS METHODOLOGY

JOBS

While recent decades have seen a shift from agriculture and manufacturing to services, a vast number of critical industries and jobs still depend upon the ecosystems in which they are performed. These jobs and industries provide a foundation upon which the rest of the economy can grow. Analyzing the jobs and wages that depend on functioning habitats and natural resources provides an additional lens for understanding the importance of natural capital. Agriculture, Renewable Energy, and Recreation are just some of the industries that depend directly on natural capital.

In this section, we calculate the jobs and wages that depend on the Long Island Sound Basin ecosystem.

METHODS

For this analysis, we defined criteria for "Watershed Health Dependent Jobs". These criteria are intended to supplement the Bureau of Labor Statistics (BLS) Green Jobs criteria.

BLS has defined Green jobs as either:[viii]

- Jobs in businesses that produce goods or provide services that benefit the environment or conserve natural resources.
- Jobs in which workers' duties involve making their establishment's production processes more environmentally friendly or use fewer natural resources.

We define Watershed Health Dependent Jobs as either:

- Jobs in industries that would be significantly impaired by local ecosystem degradation
- Jobs in industries that significantly depend on local natural resources and/or landscape features (both biotic and abiotic) for extractive and/or non-extractive uses.
- Jobs in industries the primarily work to conserve, protect, and/or manage natural resources and landscape features

These criteria were used to identify the industries and jobs that we defined as watershed health dependent jobs. We utilized North American Industry Classification System (NAICS) and selected the specific 6-digit codes for inclusion in our employment and wages that met the criteria. To estimate the jobs supported by natural capital in Long Island Sound (LIS), we took an approach based on Kauffman et al. (2011):

- Select NAICS Codes (2012 code version) that meet the criteria outlined above.
- Using 2011 County-level data from IMPLAN® based on Quarterly BLS data, sum the number of jobs and total wages in the relevant counties. IMPLAN® data were used because of supplemental data they include for greater accuracy and completeness of data.
- Estimate indirect jobs by applying an appropriate multiplier for jobs and salaries. Jobs and wages multipliers were based on Altobello (1992), Latham and Stapleford (1987), and Pomeroy (2013).

viii http://www.bls.gov/green/green_definition.pdf)

Sector	Wages Multiplier	Jobs Multiplier
General	2.20	1.80
Commercial Fishing	2.72	1.26
Seafood product preparation and packaging	2.71	2.84
Ship building and repairing	2.80	2.29
Boat building	2.71	1.90
Transport by water	2.66	3.42
Scenic and sightseeing transportation and support activities for transportation	2.97	1.94
Other amusement and recreation industries	2.73	1.28

Source: Altobello (1992), Latham and Stapleford (1987), and Pomeroy (2013)

APPENDIX F: GIS SOURCES

NATIONAL LAND COVER DATABASE 2006

http://www.mrlc.gov/

"The National Land Cover Database (NLCD) serves as the definitive Landsat-based, 30-meter resolution, land cover database for the Nation. NLCD provides spatial reference and descriptive data for characteristics of the land surface such as thematic class (for example, urban, agriculture, and forest), percent impervious surface, and percent tree canopy cover. NLCD supports a wide variety of Federal, State, local, and nongovernmental applications that seek to assess ecosystem status and health, understand the spatial patterns of biodiversity, predict effects of climate change, and develop land management policy. NLCD products are created by the Multi-Resolution Land Characteristics (MRLC) Consortium, a partnership of Federal agencies led by the U.S. Geological Survey."

US FISH & WILDLIFE SERVICE: NATIONAL WETLANDS INVENTORY

http://www.fws.gov/wetlands/

"This data set represents the extent, approximate location and type of wetlands and deepwater habitats in the United States and its Territories. These data delineate the areal extent of wetlands and surface waters as defined by Cowardin et al. (1979). Certain wetland habitats are excluded from the National mapping program because of the limitations of aerial imagery as the primary data source used to detect wetlands. These habitats include seagrasses or submerged aquatic vegetation that are found in the intertidal and subtidal zones of estuaries and near shore coastal waters. Some deepwater reef communities (coral or tuberficid worm reefs) have also been excluded from the inventory. These habitats, because of their depth, go undetected by aerial imagery. By policy, the Service also excludes certain types of "farmed wetlands" as may be defined by the Food Security Act or that do not coincide with the Cowardin et al. definition. Contact the Service's Regional Wetland Coordinator for additional information on what types of farmed wetlands are included on wetland maps."

USGS NATIONAL MAP OF HYDROGEOGRAPHY

http://nhd.usgs.gov/

"The National Hydrography Dataset (NHD) and Watershed Boundary Dataset (WBD) are used to portray surface water on The National Map. The NHD represents the drainage network with features such as rivers, streams, canals, lakes, ponds, coastline, dams, and streamgages. The WBD represents drainage basins as enclosed areas in eight different size categories. Both datasets represent the real world at a nominal scale of 1:24,000-scale, which means that one inch of The National Map data equals 2,000 feet on the ground. To maintain mapping clarity not all water features are represented and those that are use a moderate level of detail."

ARCGIS SERVER IMAGE SERVICES ("LONG_ISLAND_SOUND_SANDY_BEACHES")

http://www.orthos.dhses.ny.gov/
http://cteco.uconn.edu/map_services.htm

6-inch orthophotography image services of New York and Connecticut were utilized to draw 1,404 custom-drawn polygons of sandy beaches totaling 3,663.74 acres. The imagery is rendered from a range of dates from 2008 - 2013 for New York and 2013 for Connecticut.

APPENDIX G: ALTOBELLO COMPARISON

METHODOLOGY

The enormous worth of ecosystem services was estimated by Dr. Marilyn Altobello through an ecosystem service valuation of the Long Island Sound in 1992.[64] For the past twenty years, this study has been cited extensively by politicians, decision-makers, and a wide group of stakeholders. The study valued services such as recreation ($5.2 billion, 1990 USD), goods from the commercial fishery in the Sound ($148.4 million, 1990 USD), and ecosystem services produced by coastal wetlands ($93.8 million, 1990 USD). Altogether, Altobello estimated a 1990 value of $5.5 billion for the Sound.

This study provides an update to the 1992 report. Our goal was to incorporate the same outputs and methods as Altobello's analysis, while also including new data. An update was essential, as much more primary data are available today than 20 years ago. We included more recent data, local primary valuations where Altobello could not, and new valuation methods.

Use Value

Commercial fishing

Data on commercial fishing landings in the states of Connecticut and New York were collected from the National Marine Fisheries Service. Both the weight harvested and the value of the catch has decreased since 1990 (Figure G1).

Swimming and boating

The direct values for swimming and boating were calculated using the formula from Altobello 1992:

D=R*P*N*F

D represents the estimated total number of activity days; R is the participation rate of the activities, in number of days per year; P is the estimated 2011 population of the eight coastal counties in New York and Connecticut (Table G1); N is a demand distribution factor which relates the demand for Long Island Sound resources by both residents and non-residents; and F, the facility coefficients, represents the estimate of a recreation activity day that is met by facility units, such as beaches,

FIGURE G1 FISHERY LANDING WEIGHT AND VALUE OVER TIME

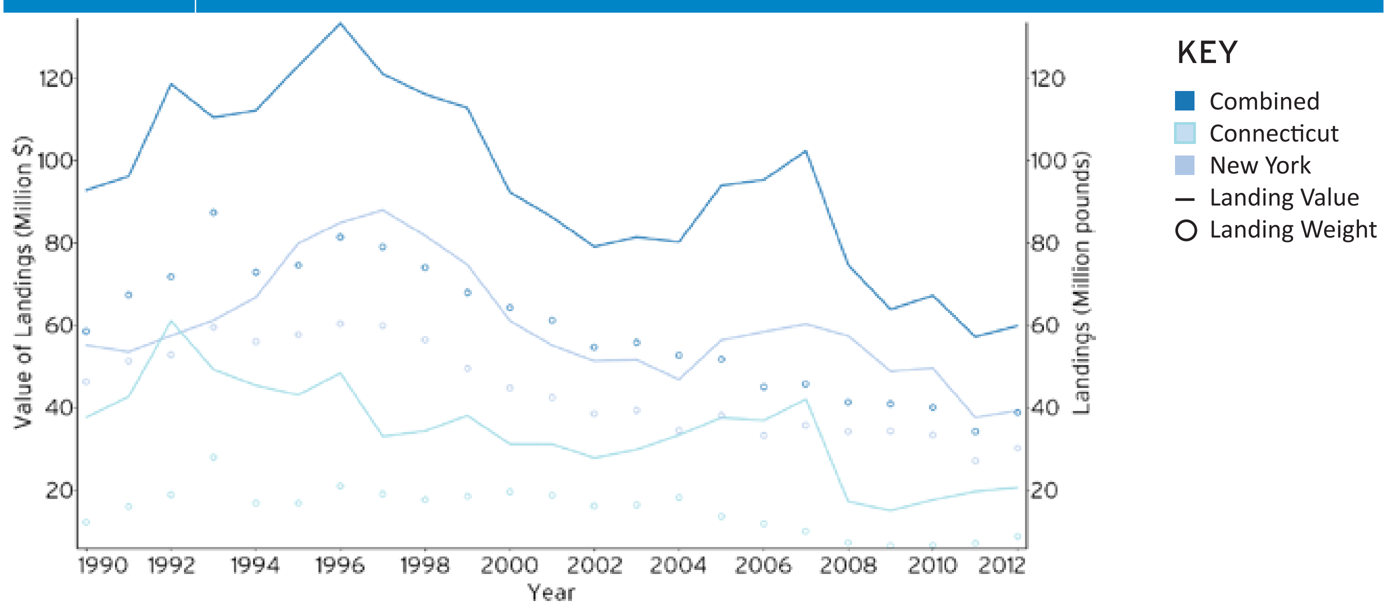


TABLE G1	POPULATION IN COASTAL COUNTIES OF CONNECTICUT AND NEW YORK IN 1990 AND 2011*		
State	**County**	**1990 population**	**2011 population**
CT	New London	254,957	273,502
CT	Middlesex	143,196	166,043
CT	New Haven	804,219	861,113
CT	Fairfield	827,645	925,899
NY	Westchester	874,866	955,899
NY	Nassau	1,287,348	1,344,436
NY	Suffolk	1,321,864	1,498,816
NY	Queens	1,951,958	2,247,848
Total		***7,466,053***	***8,273,556***

Source: US Census Bureau

*To provide a comparison with the 1992 Altobello study, we did not include the population of the Bronx.

boat ramps, and slips or moorings. More in-depth information about this formula can be found in Altobello's study.

Updated participation rates were obtained from a study of marine recreation in the nearby Peconic estuary by Opaluch et al. in 1999.

Activity days for swimming are estimated at 38,367,598 days per year and for boating at 44,818,261 days per year. To find the value of these activities, user values per day are taken from Opaluch et al. 1999 ($13/day for swimming $28/day for boating) and inflated to 2011 dollars.

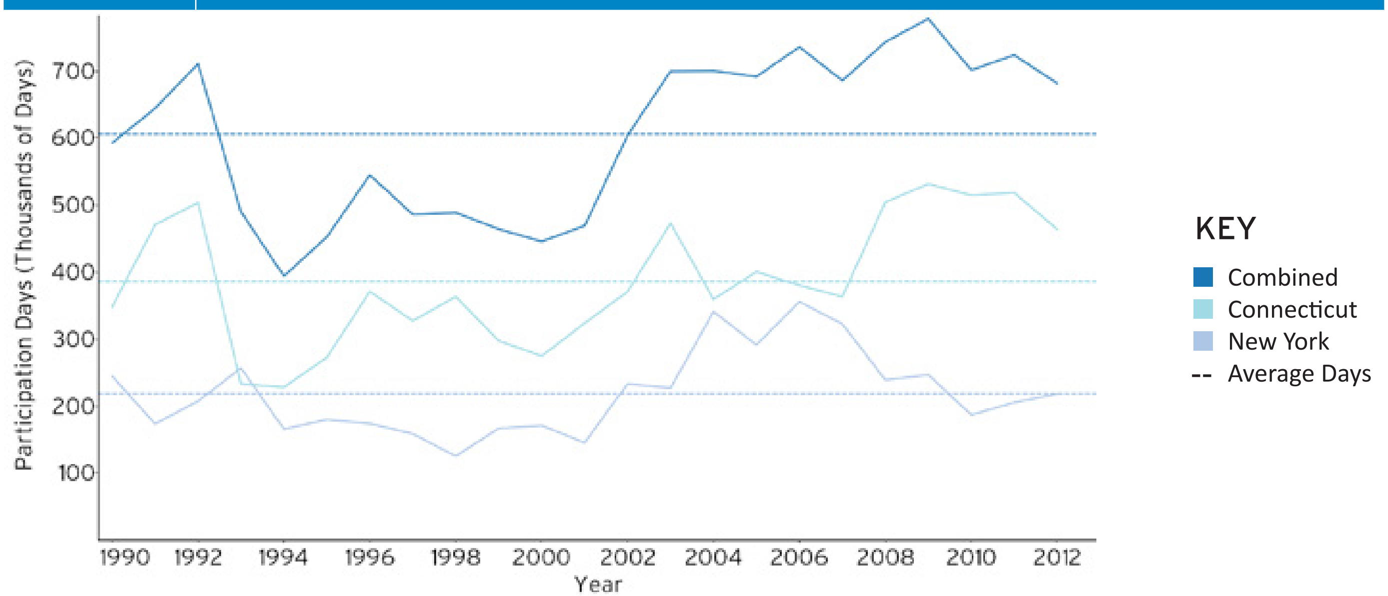
Fishing

The Marine Recreational Fishery Statistics (MRFS) survey provides participation data for recreational fishing in the states of Connecticut and New York (Figure G2).

Following Altobello, participation rates of 4.5 days per fisherman per year for Connecticut and 6.75 days per fisherman per year in New York are used. Using the MRFS survey data and participation rates, we calculated a total of 1,739,583 fishing days per year in Connecticut and 1,471,378 in New York (assuming, like Altobello, that 1/3 of New York anglers fish in the Long Island Sound). Adding these estimates together, the total estimated fishing days in the Long Island Sound are estimated to be 3,095,862.

The value of recreational fishing per day (from Opaluch et al. and inflated to 2011 dollars) allows us to calculate the use value by multiplying total fishing days by value per day.

FIGURE G2 | PARTICIPATION IN RECREATIONAL FISHING IN ANGLING DAYS PER STATE



Direct Effects

Direct effects include direct expenditures made to participate in an activity, such as gas for a motor boat, ice, fishing gear, and fishing licenses. Direct effects can be thought of as the "first round" of spending associated with an activity.

Boat purchases and trip related expenditures associated with LIS for the state of New York were estimated from a study by Connelly et al. Based on direct effects per boating day in New York, estimated direct effects for Connecticut were calculated. Oh et al. and Thompson and Wagenhals estimate the direct effects of beach swimming. From their data, we take an average spending per day of $51. The direct effects of swimming can then be calculated as spending per day multiplied by the estimated number of swimming days. Retail sales for saltwater sportfishing in Connecticut and New York are calculated by Southwick Associates for 2011.

Multiplier effects represent the indirect and induced effects that result from the direct effects of an activity. These include wages paid to employees who provide services to the industry in question, and the subsequent expenditures made with those wages. These are calculated using multipliers (Table G2).

Direct effects multiplied by the corresponding multiplier yields the total direct, indirect, and induced effects of the industry in question. Thus, to determine only the indirect and induced effects, direct effects must be subtracted from this total.

TABLE G2 ECONOMIC MULTIPLIERS USED

Activity	Multiplier
Beach Swimming	2.27186
Sportfishing	2.41674
Boating	2.2
Commercial Fishing & Shellfishing	2.8

Source: Altobello 1992

Intrinsic Value

Due to lack of information, we employ Altobello's method of estimating this value. A study by Fisher and Raucher estimate that intrinsic values are typically 50 percent of total recreational use value. Thus, we use half of recreational use value to estimate the intrinsic value of Long Island Sound.

Wetland Value

Coastal wetland value was evaluated using the benefit transfer method described in the report, and using GIS information to provide an estimate of coastal wetland acreage adjacent to the Sound.

LONG ISLAND SOUND'S EFFECTS ON THE ECONOMY

Table G3 shows the results of our update to Altobello's study. Inflating Altobello's direct expenditures and multiplier effects to 2011 USD results in an estimated contribution of $8.6 billion to the local economy. Our update of these economic effects totals $31.1 billion dollars annually (2011 USD), more than three times the values found by Altobello.

TABLE G3	COMPARISON OF UPDATED ECONOMIC EFFECTS			
Study	**Activity**	**Direct Expenditures**	**Multiplier Effects**	**Total**
Altobello	Commercial Fishing		$164,186,539	***$164,186,539***
	Recreation	$3,764,845,520	$4,714,717,998	***$8,479,563,518***
Earth Economics Update	Commercial Fishing		$103,123,870	***$103,123,870***
	Recreation	$10,014,435,459	$21,022,757,733	***$31,037,193,192***

ALTOBELLO COMPARISON SOURCES

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APPENDIX H: IMPLEMENT NEW SOCIOECONOMIC INDICATORS

The Long Island Sound Study has made available to the public on their website a comprehensive list of long term indicators for measuring the conditions of the Sound over time. These indicators track degradation factors as well as restoration efforts and are organized into four categories: Water Quality, Marine and Coastal Animals, Habitats, and Land Use and Population. Within those categories are sub-categories that the LISS has populated including Health/Condition, Response/Performance, Historical Background, and Socioeconomic.

Long Island Sound Study is at the forefront in the United States in monitoring indicators for large water bodies. Most of the suggested indicators will be socioeconomic and related to human population land use at various scales. The Long Island Sound Study provides an opportunity to measure some indicators of natural capital that are unconventional.

On the next page, we use ecosystem service categories as a framework for suggesting new indicators and attempt to classify them according to LISS taxonomy. Many indicators are useful measurements of the quality of several ecosystem services and land covers, and also represent emergent properties of the socio-ecological-economic system. Depending on the future focus of LISS, it may consider changing its taxonomy to accommodate more diverse indicators and collaborators.

One of the most valuable or costly exchanges between natural and human capital is that of human health. Geospatial data, awareness of contaminants, biomedical research, and a growing concern about the fiscal sustainability of public health costs are all converging to enhance understanding of the connections between ecosystems and health. The Centers for Disease Control and the World Health Organization, for example, have each established environmental public health indicators, including statistics on birth defects, bio-monitoring of pollution exposure (pollutant concentrations in blood and urine), childhood lead poisoning, adult and childhood cancers, and developmental disabilities. The Department of Public Health of the State of Connecticut curates data sets that include asthma, cancer, hospitalization rates, tumor registry, and West Nile virus.

VALUATION METHODS USED IN PRIMARY STUDIES

Indicator	Primary Earth Economics Ecosystem Service	LISS Category	LISS type
Agricultural Sales	Food	Land Use and Population	Socioeconomic
Percentage of Farmland with Organic/ Sustainable Practices	Food	Land Use and Population	Response Performance
Number of Acres in Agriculture	Food	Land Use and Population	Health/Condition
Wood heating Sales/Volumes	Energy & Raw Materials	Land Use and Population	Socioeconomic
Hydroelectricity Sales/Generation/ Capacity	Energy & Raw Materials	Land Use and Population	Socioeconomic
Biomass Electricity Sales/Generation/ Capacity	Energy & Raw Materials	Land Use and Population	Socioeconomic
Wood and Wood Product Sales (Timber, Lumber, Paper)	Energy & Raw Materials	Land Use and Population	Socioeconomic
Number of water utility rate payers	Water Supply	Land Use and Population	Socioeconomic
Total water utility rates paid	Water Supply	Land Use and Population	Socioeconomic
Total Operations Costs of Drinking Water Filtration and Treatment	Water Supply	Water Quality	Socioeconomic
Irrigation volumes and value	Water Supply	Land Use and Population	Socioeconomic
Hypothetic or real Value of Carbon Assets and Liabilities	Climate Regulation	Land Use and Population	Socioeconomic
Asthma Rates and Health Costs	Air Quality	Land Use and Population	Health/Condition
Cost of Storm and Extreme Weather Event Damages	Moderation of Extreme Events	Land Use and Population	Socioeconomic
Total Operations Cost of Waste Treatment Plants	Waste Treatment	Land Use and Population	Socioeconomic
Total Annual Value of Goods Moved Through Long Island Sound	Water Regulation	Land Use and Population	Socioeconomic
Total Annual Value of Conservation Land Acquisitions and Easements	Habitat and Nursery	Land Use and Population	Socioeconomic
Trends of Second Home Market Value	Aesthetic	Land Use and Population	Socioeconomic
Direct and indirect economic impacts of recreational activities can be monitored through the number of registered recreational vessels*, park attendance, number of chartered fishing trips, equipment sales, etc.	Recreation	Land Use and Population	Socioeconomic

* For example, the number of registered recreational boats was used as an input for a model analyzing direct, indirect, and induced economic effects in the 2012 New York State recreational Boater Survey.

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