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Bulletin No. 37: Living Resources and Habitats of the Lower Connecticut River

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Connecticut College

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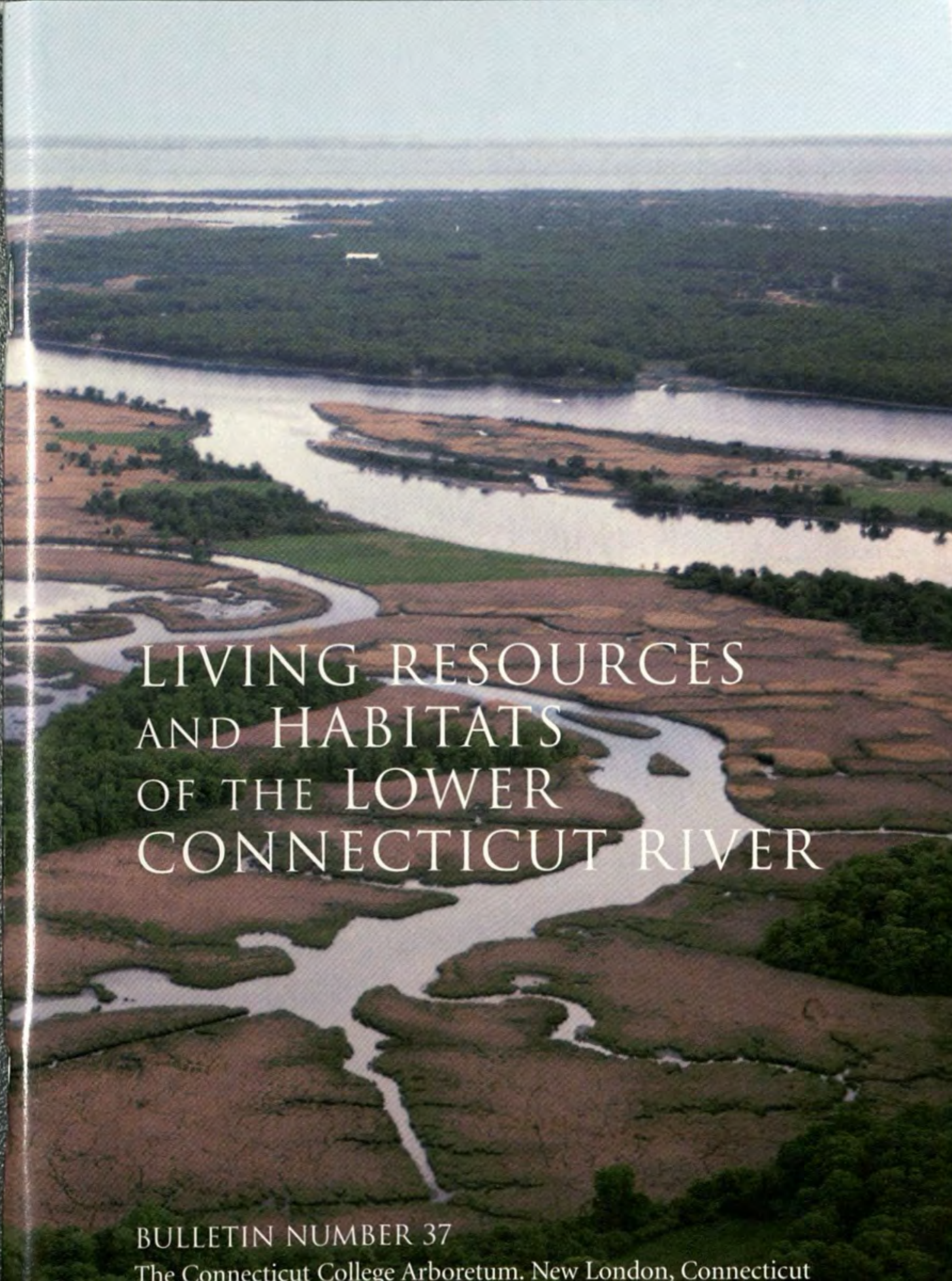

LIVING RESOURCES AND HABITATS OF THE LOWER CONNECTICUT RIVER

BULLETIN NUMBER 37
The Connecticut College Arboretum, New London, Connecticut

CONNECTICUT COLLEGE

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On the cover: View south over Lord Cove, Lyme, with the Connecticut River and Long Island in the background. Lord Cove is a brackish tidal marsh dominated by narrow-leaved cat-tail. (Quarrier)

LIVING RESOURCES AND HABITATS OF THE LOWER CONNECTICUT RIVER

Edited by Glenn D. Dreyer & Marcianna Caplis

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The Connecticut College Arboretum. New London, Connecticut

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NOTICE TO LIBRARIANS

This is the 37th volume of a series of bulletins published by the Connecticut College Arboretum, formerly named the Connecticut Arboretum. Bulletins 1-30 were published as Connecticut Arboretum Bulletins.

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Dr. William A. Niering receiving an award from Connecticut Department of Environmental Protection (DEP) Commissioner Sidney J. Holbrook (left) and DEP Biologist Stephen Gephard (center) at a 1996 ceremony celebrating the 25th anniversary of the Ramsar Convention on Wetlands of International Importance.

FOREWORD

THE CONNECTICUT RIVER is one of the most remarkable ecosystems in New England. At one time not long ago, parts of the river were referred to as the best landscaped sewer in the nation. Today it has come full circle to be a very high quality, fully functioning ecological system. The Connecticut is also one of only a few large rivers in the United States that does not have a major port at its mouth. Considering the state's population density, the lower river is amazingly rural and scenic.

The focus here is on the lower reaches of the Connecticut, that section below Portland and Cromwell that is a major New England estuary and tidal river. It has been recognized by an international convention as globally significant, and our aim is to help readers understand why scientists and conservationists believe it is so special. This publication is the result of a cooperative effort among the Connecticut Department of Environmental Protection (DEP), the U.S. Fish and Wildlife Service, and Connecticut College, with experts from each organization contributing their knowledge to the final product. It is the second Arboretum Bulletin funded by the Connecticut DEP Office of Long Island Sound Program's Long Island Sound Fund, the first being "Tidal Marshes of Long Island Sound, Ecology, History and Restoration." This publication is dedicated to the memory of Dr. William A. Niering, wetland ecologist and Connecticut College Professor.

Glenn D. Dreyer
Charles and Sarah P. Becker '27 Arboretum Director

ACKNOWLEDGEMENTS

THE EDITORS AND AUTHORS wish to express our gratitude to the following individuals who helped make this bulletin possible: Robert Askins and Catherine Niering for proofreading and editorial input; Susan Lindberg, Connecticut College, for publication design; Michael Toti for artwork; Rosemary Malley, Connecticut Department of Environmental Protection, for GIS maps; Andrew Milliken, U.S. Fish and Wildlife Service; Kevin McBride, University of Connecticut.

INTRODUCTION

By Marcianna Caplis
United States Fish and Wildlife Service

THE RIVER

A DOMINANT FEATURE of the northeastern United States, the Connecticut River is the longest and largest river system in New England and, at its mouth, the widest. Its headwaters lie in the mountains of northern New Hampshire above Fourth Connecticut Lake near the Canadian border, from which it flows south some 660 kilometers (410 miles) to Long Island Sound. The river provides nearly 70 percent of the freshwater input into that nationally recognized estuary. The watershed basin encompasses an area of approximately 2.9 million hectares (7.1 million acres), or over 28,500 square kilometers (11,000 square miles), located in four states — New Hampshire, Vermont, Massachusetts, and Connecticut. There are 16 dams on the river, mostly utility-owned, that impound nearly 200 miles of its length, and many other dams on its tributaries. The lower 96 kilometers (60 miles) of the river, however, from Windsor Locks near the Connecticut-Massachusetts border to Long Island Sound, are both free-flowing and tidal. The river's tidal boundary reaches 90 kilometers (56 miles) from the mouth, and the lower 58 kilometers (36 miles) are the primary subject of this bulletin.

The Connecticut River and its huge watershed are of major importance to the region, providing essential habitats, nutrients, and energy flow for a great many species of native plants, fish, and wildlife. The river also provides homes, jobs, and recreational opportunities to over two million people living in the nearly 400 cities and towns in its watershed. At the lower tidal reaches of the river, at its confluence with Long Island Sound, the river, its associated tidal wetlands, and wetlands-dependent species achieve their greatest prominence and ecological significance.

The Connecticut River is the only principal river in the northeastern United States without a major port, harbor, or urban area at its mouth. This is the result of shifting sandbars in Long Island Sound that impede navigation. This situation has served to preserve the largely rural character of the regional landscape and maintain the river's extraordinary assemblage of natural and relatively undisturbed biotic communities. The lower Connecticut River (see map in center of this bulletin), beginning near its mouth at Long Island Sound and continuing upstream for 58 kilometers (36 miles), contains one of the least developed or disturbed large-river tidal marsh systems in the United States, and the most pristine large-river tidal marsh system in the Northeast. There are no other areas in the Northeast that support such extensive or high quality fresh and brackish tidal wetland systems. These tidal river waters and marshes provide essential habitat not only for several federally listed and candidate species and globally rare species, such as bald eagle, shortnose sturgeon, piping plover, and puritan tiger beetle, but also for dozens of state-listed endangered and threatened species. Concentrations of waterfowl, especially American black duck, in this section of the river are among the highest and most significant in the region. Several important restoration programs for anadromous fish species, including Atlantic salmon and American shad, are underway in the Connecticut River, especially at its mouth and where major tributaries join the main stem.

The Connecticut River Estuary is a single integrated complex composed of many individual wetlands units, or core sites, and shallow water riverine habitats, all of which are inextricably linked by the tidal waters of the Connecticut River itself. There is a tremendous degree of ecological interaction and interdependence among its tidal waters, tidal wetlands, and adjacent uplands.

The wetlands and waters in the estuarine and tidal river complex of the lower river, with its extensive, high quality tidal freshwater and brackish marshes and remarkable clustering of rare and endangered species, waterfowl, and anadromous fishes, are the focus of its designation as a Wetland of International Importance under the Ramsar Convention.

THE RAMSAR CONVENTION

IN 1963, the First European Meeting on the Conservation of Wildfowl convened and recommended both the creation of a European network of refuges for wild birds, and the adoption of an international convention to ensure this network's effective and coordinated operation. Additional conferences in 1966 and 1968 explored the adoption and content of a convention on the conservation of wetlands of international importance. Final text of the agreement was adopted in 1971 in Ramsar, a small town on the shores of the Caspian Sea in Iran, which has lent its name to the Convention on Wetlands of International Importance. The Convention became effective in 1975, and has been modified over the years while still supporting its fundamental principles:

- people and their environment are interdependent;
- wetlands have fundamental ecological functions as regulators of water regimes and as habitats supporting a characteristic flora and fauna, especially waterfowl;
- wetlands constitute a resource of great economic, cultural, scientific, and recreational value;
- the progressive encroachment on and loss of these wetlands must be stemmed;

- waterfowl in their seasonal migrations may transcend frontiers and should therefore be regarded as an international resource;
- the conservation of wetlands and their flora and fauna require far-sighted national policies combined with coordinated international action.

Since its inception, the Convention on Wetlands of International Importance has striven to stem the loss of wetlands and to ensure their conservation worldwide. The Convention promotes international cooperation with non-regulatory guidance in implementing its goals of designating wetlands for inclusion in the List of Wetlands of International Importance, promoting the wise use of wetlands and creating wetland reserves.

Each participating country designates wetlands based on their internationally significant ecological, botanical, zoological, limnological, or hydrological values. The categories for selecting internationally significant wetlands are:

- representative or unique wetlands in a region;
- wetlands using plants and animals, especially rare and endangered species, as indicators of importance;
- wetlands of particular value to waterfowl.

In the late 1970's, the Coastal Area Management Program (now called the Office of Long Island Sound Programs) and the Geological and Natural History Survey of the Department of Environmental Protection (DEP) began a systematic search for rare plants and the characterization of the outstanding brackish and tidal-fresh marshes of the lower Connecticut River. In 1982, in recognition of the regional significance of the river, DEP proposed to the National Oceanic and Atmospheric Administration that portions of the river should be designated as a National Estuarine Sanctuary and submitted a formal application in 1991. Due to funding constraints, this designation did not occur. In 1991, the U.S. Fish and Wildlife Service's Southern New England – Long Island Sound Coastal and Estuary Office identified the Connecticut River as one of 40 significant coastal areas in southern New England and recommended it as a potential Ramsar site. In 1993, The Nature Conservancy identified the lower Connecticut River as one of 40 Last Great Places in the Northern Hemisphere. On October 14, 1994, at a ceremony in Gillette Castle State Park attended by Interior Secretary Bruce Babbitt, the Connecticut River Estuary and Tidal River Wetlands Complex was designated as the nation's fourteenth Ramsar site (Figure 1).

By 1998, 112 countries were Contracting Parties to the Ramsar Convention, having listed 931 sites covering about 70 million hectares. To date, the U.S. has added 17 sites to the List of Wetlands of International Importance.

Inspired by the Ramsar designation, our aim in producing this publication is to provide a brief, accessible overview of the living resources of the lower Connecticut

River. By educating students, conservationists, local officials, and citizens in general concerning the value of this unique ecological complex, we hope to increase support for its conservation and protection. Our story builds from basic presentations of geology, hydrology, and human aquatic use history to a chapter on the biotic communities of the river system. Chapters follow on wildlife and fish, two important components in the original Ramsar Convention agreement. The bulletin ends with sections on stewardship of these natural resources and on management issues particular to the lower river.

Figure 1. US Secretary of the Interior Bruce Babbit (standing) addresses an October 1994 ceremony dedicating the Connecticut River as a Ramsar wetland of international importance. With the river in the background, Babbit was joined by Senator Joseph Lieberman (left), and DEP Commissioner Timothy Keeney (right).

GEOLOGY OF THE LOWER CONNECTICUT RIVER VALLEY

Ralph Lewis
Geological and Natural History Survey
Connecticut Department of Environmental Protection

NORTH OF HARTFORD, the Connecticut River flows southward through the middle of the Connecticut Valley (Figure 1). The position of this valley was established during Mesozoic time (225-180 million years ago), as the Atlantic Ocean was forming, and the middle part of Connecticut was rifted apart. Today, the "Long Tidal River" bisects the relatively soft, Mesozoic-aged sedimentary rocks that define the Connecticut Valley, and flows fairly unrestricted over the former lakebed of glacial Lake Hitchcock. From Hartford south to Middletown, the presence of the resistant basalts (traprock) that form the Metacomet Ridge, Hanging Hills, Mount Higby, etc. has confined the river to a south-southeasterly route along the easternmost side of the

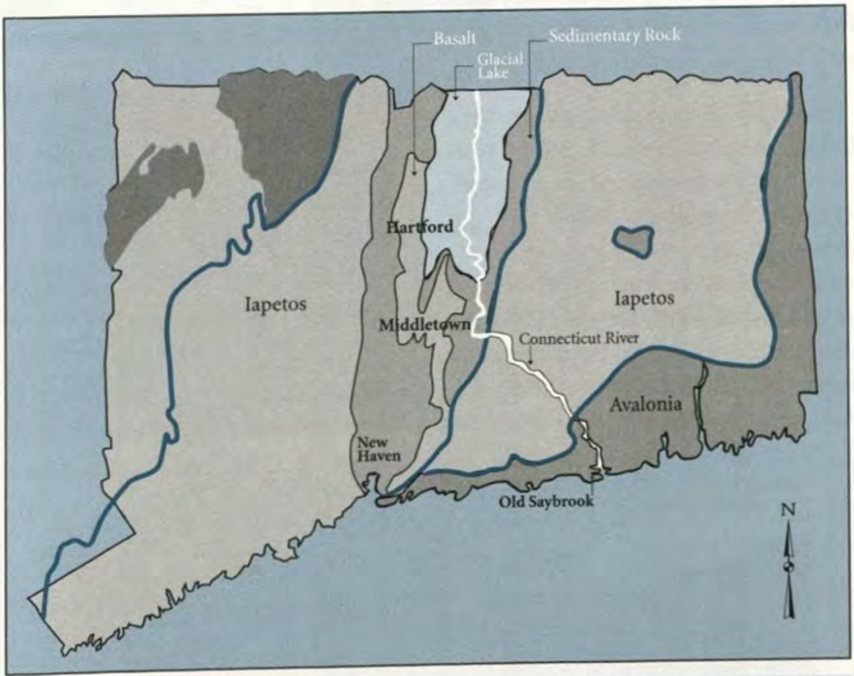


Figure 1. Simplified geologic map of Connecticut showing the path of the Connecticut River across glacial lake deposits and sedimentary rocks to the north, and the gneisses, schists, and granites of the Iapetos and Avalonian terranes to the south.

Valley. At Middletown, the Connecticut River turns more eastward, exits the softer sedimentary rocks of the Connecticut Valley, and flows southeastward through a confined, bedrock-walled valley cut in hard Paleozoic-aged (400- 500 million years old) metamorphic rocks (Iapetos and Avalonia, Figure 1).

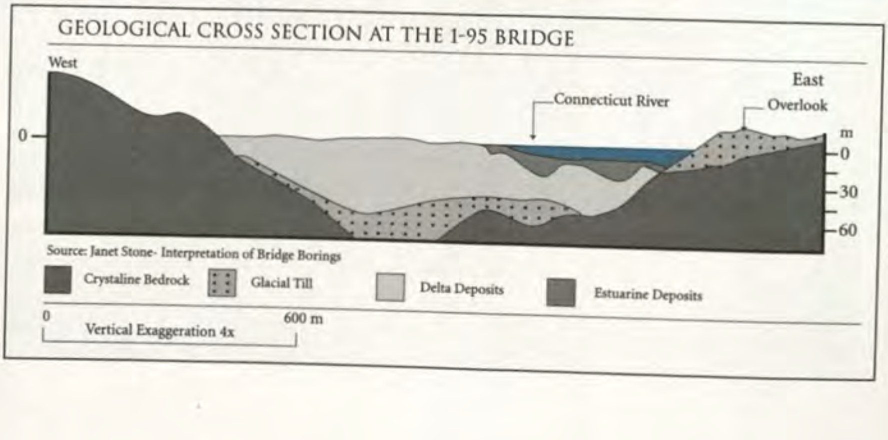
The interesting eastward turn of the Connecticut River at Middletown (Figure 1) has spawned a geologic "folk history" that tells of a former course of the river ending at New Haven. There is *no* evidence for this, and, in fact, the traprock ridges of the Connecticut Valley have precluded such a route since they were faulted and uptilted about 180 million years ago. The present route of the lower river is a natural result of its geologic past. Precursors of the modern Connecticut River have probably flowed from Middletown to Old Saybrook for at least 97 million years (pre-Late Cretaceous) and possibly as long as 180 million years.

The hills that flank the Connecticut River valley from Middletown to Old Saybrook are the eroded remnants of 500 million year old rocks that were last heated and metamorphosed (changed) about 300 million years ago as an ancient continent called Avalonia was crushed against ancient North American continent (Figure 1). This continental "fender bender" formed the Appalachian Mountains, and made Avalonia a permanent resident of southeastern Connecticut. Rock ridges now follow the trend of broad bands of gneisses, schists, and granites that were brought to their present alignment during the continental collision.

Today, the lower river occupies a deep, glacially scoured bedrock valley controlled by a north- and northwest-trending zone of faults/fractures that cut across the alignment of the metamorphic rocks. The deep bedrock valley bottom lies at a depth of 45 meters (150 feet) below the present river at Portland and at 76 meters (250 feet) below sea level at I-95, where it is slightly to the west of the

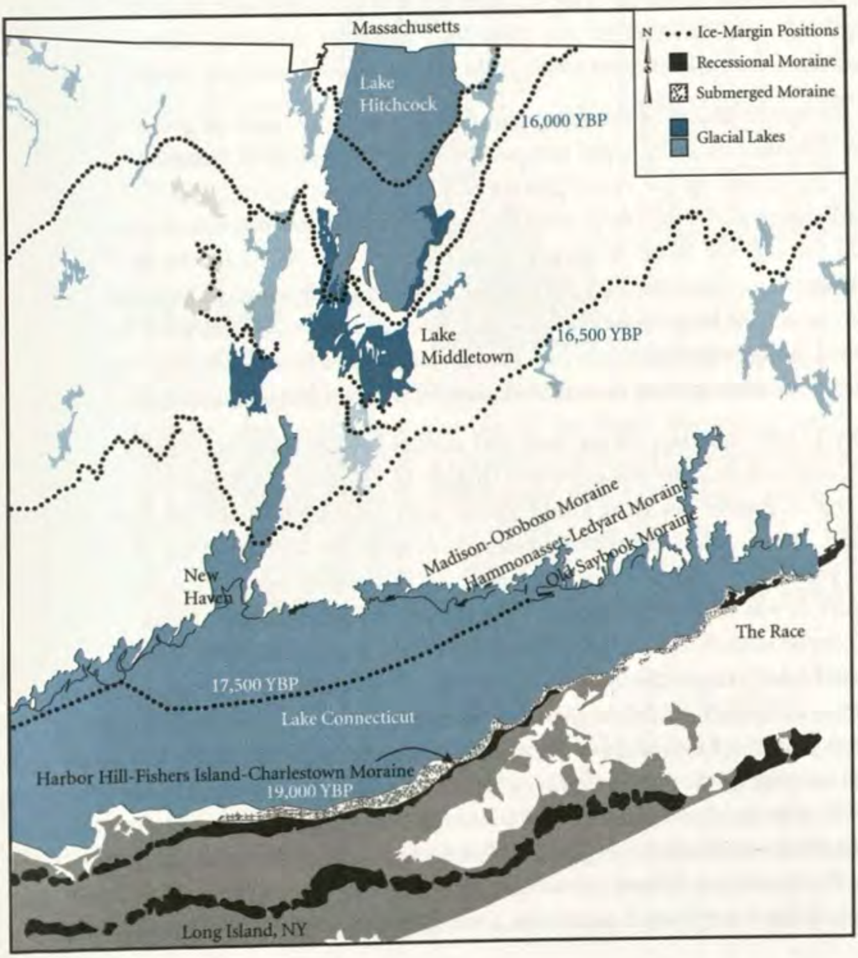
Below: Figure 2. Geologic cross section at the I-95 bridge showing the deep bedrock valley of the Connecticut River (west of the present river) filled with ice-marginal glacial delta deposits which were, in turn, incised and filled with estuarine deposits. Prior to their incision, the ice-marginal delta deposits choked the valley.

Opposite page: Figure 3. Regional glacial map showing major glacial lakes, moraines and ice-margin positions. The dates indicated for moraines and ice-margin positions are years before present (YBP). Adapted from Stone, et al. 1998



present river beneath Old Saybrook (Figure 2). Offshore from Saybrook Point, the buried, ancestral Connecticut River valley bottom lies at depths greater than 100 meters (350 feet) below sea level and extends beneath the Cretaceous-aged coastal plain strata underlying Long Island.

The fault and fracture zones exploited by the proto-Connecticut River cut across the "grain" of the older metamorphic rocks of eastern Connecticut, forming a north- and northwest trending zone of weakness that was particularly susceptible to stream and glacial erosion. Sometime after the metamorphic rocks were faulted and fractured, and before the deposition of the Cretaceous coastal plain strata of Long Island (100 million years ago), early variations of the river established a southeastward flow across the rocks of Avalonia. Over the past 2 million years (the Quaternary Period), this ancestral valley was glacially scoured, and the stage was set for the development of the modern river. The Housatonic River between Bridgewater and Shelton established a similar path across the Iapetos Terrane of western Connecticut.



At least two continental ice sheets are known to have advanced into Connecticut from the north. The older of the documented glaciations is thought to have occurred in Illinoian time (130,000 years ago). Although this glacier reached as far south as Long Island, its role in shaping Connecticut's landscape is poorly known. During the last glaciation (late Wisconsinan), ice advanced into northern Connecticut about 25,000 years ago, reached its terminal position on Long Island by 22,000 years ago, and began its northward melt back by about 20,000 years ago. The advance and retreat of the last ice sheet created many facets of the modern landscape, and left behind most of the unconsolidated materials (sand, gravel, silt, clay, till) that lie on top of bedrock in many places in the Connecticut River valley.

As the Wisconsinan glacier advanced from the north, it scoured and plucked the bedrock surface and deepened existing valleys. The glacial ice was at least a mile thick over coastal Connecticut, and the tremendous weight of the ice (more than 200 tons per square foot) depressed the earth's crust by hundreds of feet. The enormous quantity of water that was tied up in the ice sheet resulted in a worldwide sea level lowering of about 400 feet. The shoreline was more than 100 miles seaward, and the Continental Shelf was subaerially exposed south of the glacial terminus on Long Island.

The northernmost of the two major glacial moraines (ridges of glacial debris) that were deposited on Long Island between 20,000 and about 19,000 years ago can be seen from the mouth of the river. This moraine, called the Harbor Hill-Fishers Island-Charlestown, forms the north shore of Long Island and extends eastward from Orient Point through the "Race" to form Fishers Island (Figure 3). As the ice front retreated northward away from the Harbor Hill-Fishers Island-Charlestown moraine, the moraine acted as a dam impounding glacial meltwater behind it. Glacial Lake Connecticut formed in the basin that is now occupied by Long Island Sound. The lake's outlet to the lowered sea was a spillway across the Harbor Hill-Fishers Island moraine at the "Race."

By 17,500 years ago, the ice front had melted back to stand at Fenwick, where the Old Saybrook moraine was deposited (Figure 3). Glacial Lake Connecticut was about as large as present day Long Island Sound, and a similar lake occupied Block Island Sound. Debris-laden meltwater streams, flowing off the ice front, built deltas of sand and gravel into glacial Lake Connecticut. The Hammonasset-Ledyard moraine (Figure 3) was constructed slightly later, during retreat of the ice margin through the Old Saybrook/Old Lyme area. Extensive deltas associated with this ice position choked what is now the mouth of the river (Figure 2, delta deposits), and their remains form the foundation of the marsh system south of the railroad bridge. A preserved portion of one of these deltas, a flat-topped surface about 25 feet above river level, is a prominent feature that is easily seen on the west side of the river, just north of I-95. The northernmost identifiable moraine that crosses the lower river is known as the Madison-Oxoboxo (Figure 3). This feature occurs along the south side of the Falls River in Essex. At least thirteen ice-marginal deposits, with associated meltwater deltas, lie in a northward succession from Old Saybrook to Portland, Connecticut

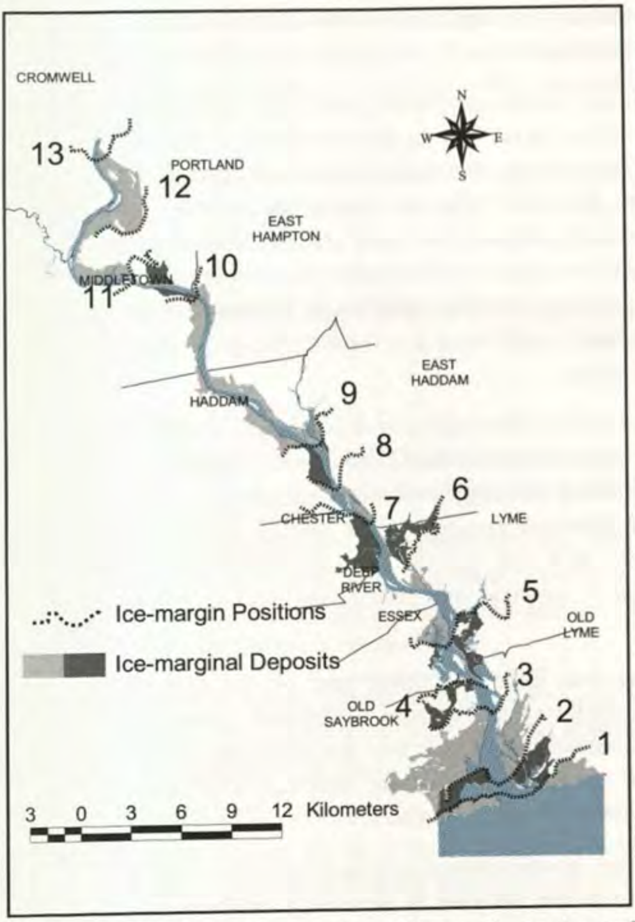


Figure 4. A regional map showing the succession of ice-margin positions between Old Saybrook and Portland. Ice-marginal glacial delta deposits (alternating light and dark gray areas south of each ice position) progressively choked the bedrock valley from south to north as the glacier melted. Most of the present-day tidal marshes in the map area developed on top of the eroded remnants of these ice-marginal deposits.

(Figure 4). This succession of deposits, including the deltas associated with the Old Saybrook, Hammonasset-Ledyard, and Madison-Oxoboxo moraines extended across, and choked, the entire valley south of Portland.

Sometime shortly after 16,500 years ago, the Wisconsinan glacier had melted out of the lower Connecticut River valley (Figure 3). In its wake, the valley south of Middletown was completely choked by a 25-mile-long mass of meltwater sediment that served as a dam for glacial Lake Middletown and its successor, glacial Lake Hitchcock. Owing to continued depression of the land, there was little gradient between glacial Lake Middletown and glacial Lake Connecticut to the south (Figure 3). This flat system probably initially consisted of a long series of sediment-dammed ponds.

The water level in glacial Lake Connecticut was slowly lowering, as the spillway at the "Race" was eroded. This gradually caused the base level for the lower Connecticut River valley system to fall, and provided an impetus for streams to begin downcutting. By 15,500 years ago, Connecticut was nearly ice free (Figure 3), glacial Lake Connecticut was completely drained, glacial Lake Middletown was draining, and incision of the entire lower Connecticut River sequence of glacial deltas was well underway. Water spilling from glacial Lake Hitchcock, to the north, was running in an established through-flowing drainage system, and ultimately the glacial deltas at the mouth of the river were incised to a depth of between 20 and 30 meters (66 to 100 feet) below present sea level (Figure 2).

As the ice sheet continued melting northward, meltwater replenished the oceans and by 15,000 years ago sea level had risen enough to begin to enter the Long Island Sound basin. Before 14,000 years ago, the encroachment of the sea was unimpeded because the land remained depressed. When rebound of the land began shortly after 14,000 years ago, the relationship between the rising sea and the rising land became a 5,000-year "horse race." Sea level rise and the rate of rebound at the coast ran a "dead heat" until about 9,000 years ago when rebound began to wane. During the "dead heat," sea level in Long Island Sound stood at a constant elevation about 40 meters (130 feet) lower than it is today.

Although the rising sea and the rebounding land were in equilibrium at 40 meters (130 feet) below present sea level along coastal Connecticut, northern New England rebounded more than southern New England because the glacier was thicker to the north. This differential rebound resulted in an overall southward tilting of Connecticut as both the land and sea were rising. This tilting allowed the Connecticut River to begin to downcut, and glacial Lake Hitchcock drained rapidly about 13,700 years ago.

The postglacial Connecticut River established itself on the drained Hitchcock lakebed, and continued southward through the established drainageway to Long Island Sound. The river eventually cut deeply into the Hitchcock lakebed. By about 9,000 years ago, the rate of rebound had waned and relative sea level rose rapidly from its position at 40 meters (130 feet) below present.

As relative sea level rose, coastal rivers could no longer downcut. These rivers began to aggrade, or adjust to the rising sea by depositing sediment. Estuarine sediments began to fill the channels cut into the glacial deltas of the lower Connecticut valley (Figure 2). By 4,000 years ago, rising sea level had reached about 7.6 meters (25 feet) below modern levels. Between 4,000 and 1,700 years ago, sea level rose at an average rate of 1.9 millimeters/year (0.08 inches/year, Patton and Horne, 1991). Floodplains and terrace surfaces that bordered the developing lower Connecticut River estuary were flooded. During the following 1,400 years, the rate of sea level rise was only 0.9 millimeters/year (0.04 inches/year) and tidal marshes expanded across these surfaces. For the past 300 years, sea level has been rising at a rate of 2.2 millimeters/year (0.09 inches/year) in the lower river, and it appears that sedimentation rates on the high marshes are sufficient to keep pace with this increased submergence rate (Patton and Horne, 1991).

Today, extensive salt and brackish-water marshes border the river from Essex southward. Upstream, ecologically significant, freshwater tidal marshes fringe the river (see the Tidal Marsh Classification of Hill and Shearin, 1970). A variety of glacially derived and estuarine sediments underlie the river, which is tidal as far north as Hartford. Sediments associated with the channel range from coarse to fine in a setting of shifting bottom configurations. Coarser sediments are generally associated with faster water movement, and the finer sediments tend to fringe the channel and extend landward.

Because tidal flux and long-shore currents produce shifting sandbars where the river meets the sound, historically the area was not friendly to deep-draft ships. Consequently, the Connecticut River is one of the few major rivers in the United States without a port city at its mouth. To this day, development along the lower valley remains relatively sparse.

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Journal of Coastal Research, Volume 16, No. 3, 2000, Coastal Education and Research Foundation, Inc., West Palm Beach, FL. (Contains updated geology, etc. in a Long Island Sound Thematic Section of 12 papers)

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HYDROLOGY OF THE LOWER CONNECTICUT RIVER

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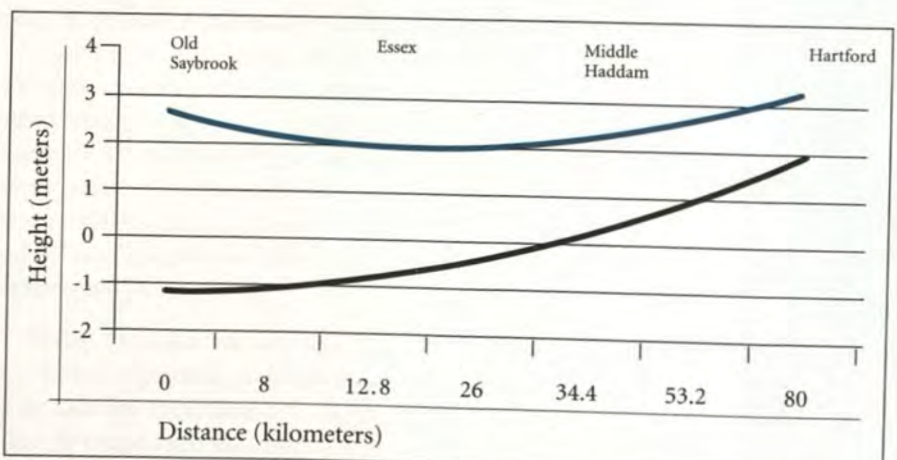
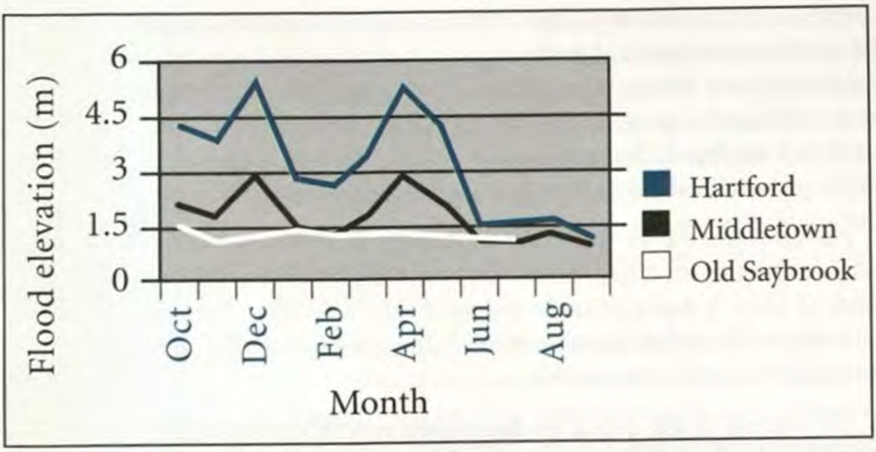
Office of Long Island Sound Programs
Connecticut Department of Environmental Protection

THE MAINSTEM of the Connecticut River is 660 kilometers (410 miles) long and drains an area of approximately 2.9 million hectares (7.1 million acres), making it the largest riverine ecosystem in the northeastern United States. The lower Connecticut is generally defined as the southernmost 58 kilometers (36 miles) of the river's mainstem, from the vicinity of Portland/Cromwell to its mouth, or about nine percent of its total length. The drainage area of this section, including the mainstem and tributaries, is approximately 46,650 hectares (115,260 acres), less than two percent of the Connecticut River's total drainage basin.

The Connecticut River provides nearly 70 percent of the freshwater input into Long Island Sound and thus exerts a profound influence on this major East Coast estuary. It has a mean freshwater discharge of 566 cubic meters/second (20,000 cubic feet/second), a rate comparable to that of major rivers such as the Hudson and Delaware. In contrast to the valleys of these rivers, the lower Connecticut River is tightly constricted by hills of crystalline bedrock. Strongly influenced by Long Island Sound, it is tidal as far north as Windsor Locks, nearly 96 kilometers (60 miles) from its mouth.

Figure 1 depicts how the elevation of various tidal stages change between Old Saybrook and Hartford. All rivers have a slope, with decreasing elevation in the downstream direction. In the case of the Connecticut River, the river surface slope is so





Opposite page: Figure 1. The elevation in meters of mean low water (black line) and mean high water (blue line) with increasing distance from the mouth of the river to Hartford. From Barrett 1989.

Above: Figure 2. Graph showing the variation in river elevation at three locations on the lower river.

gentle that the tides cause it to rise and fall. Tides are often described as a wave that gradually progresses across a waterbody. In the case of this river, high tide arrives first at the mouth, occurs one hour later at Hadlyme, and nearly three and a half hours later at Hartford. The tidal wave progresses northward at an average rate of 45 kilometers/hour (28 miles/hour).

Annual flood levels on the river are highest at Hartford, where the river is narrow and there is very little floodplain for storage (Figure 2, top line). As the river widens downstream at Middletown, the height of the floodwater is significantly lower (Figure 2, middle line). At the mouth of the river in Old Saybrook, water level heights show little or no influence from river discharge, and only fluctuate with the tides (Figure 2, bottom line).

The highest water levels and the highest volume of discharge on the river usually occur during the spring months of April and May (Figure 3) and this annual flood is referred to as the spring freshet. This freshet represents the peak of freshwater runoff associated with snowmelt in the northern New England states. In the Hartford area, a second, smaller, and earlier freshet occurs in March (Figure 3), caused by the local snowmelt in Connecticut.

The spring freshet has a marked influence on the distribution of living resources and certain habitat types in the lower Connecticut River. The strong currents and elevated flood waters associated with the freshet create a series of linear or pendant bars called riverine levees, composed of silty sands that parallel the mainstem river and create the many sheltered coves along the river. Examples include North Cove in Essex and Lord Cove in Lyme. Equivalent features found along the shores of Long Island

Sound are coastal barrier beaches. While the barrier beaches are formed by wave action and are composed of medium to coarse sands, they too create sheltered coves and embayments behind them. Within the sheltered waters created by the riverine levees two significant aquatic habitat types, tidal wetlands and submerged aquatic vegetation, are found. The prominence of levees is directly related to the height of the freshet and tends to increase in magnitude from downstream to upstream.

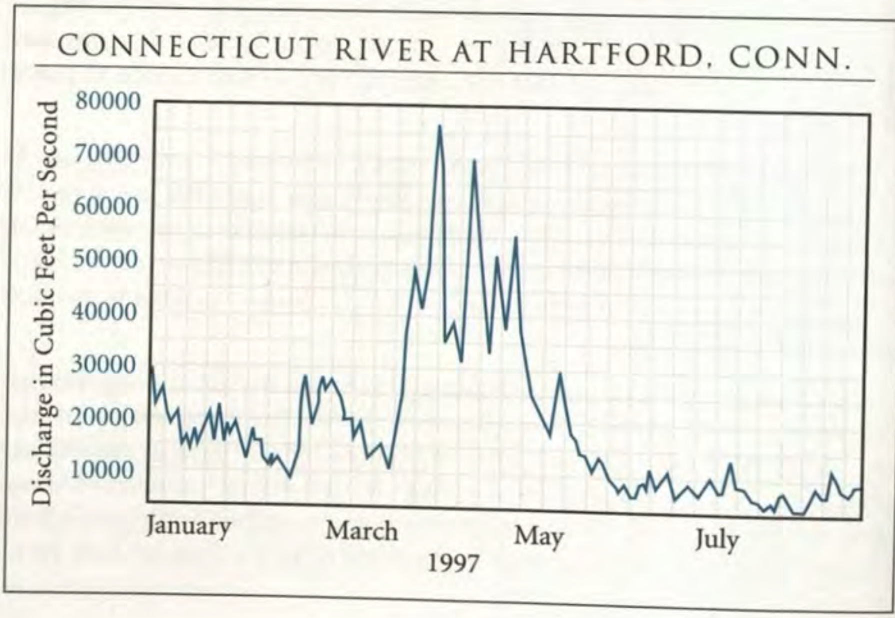
Also related to the levees are riverine floodplains, low-lying areas of land that are inundated during the spring freshet. Freshets transport tremendous quantities of silt, much of which is deposited in the quiescent floodplain areas. These highly enriched soils support floodplain forests (see the Ecology chapter) and these fertile areas are also highly desirable for agriculture.

The timing of the spring freshet coincides with the northern migration of waterfowl. In the upper reaches of the lower Connecticut River, in locations such as the Cromwell Meadows, the extensive emergent tidal wetlands are flooded for several weeks, creating temporary but natural impoundments that attract migrating waterfowl.

Below: Figure 3. Graph showing changes in the rate of river water flow at Hartford from January through July.

Opposite page: Figure 4. Salinity distribution maps of the lower river in spring and summer. In spring, the water is entirely fresh due to the great volume of freshwater from snowmelt. In response to diminishing freshwater flows during the summer, saltwater intrudes far up the estuary.

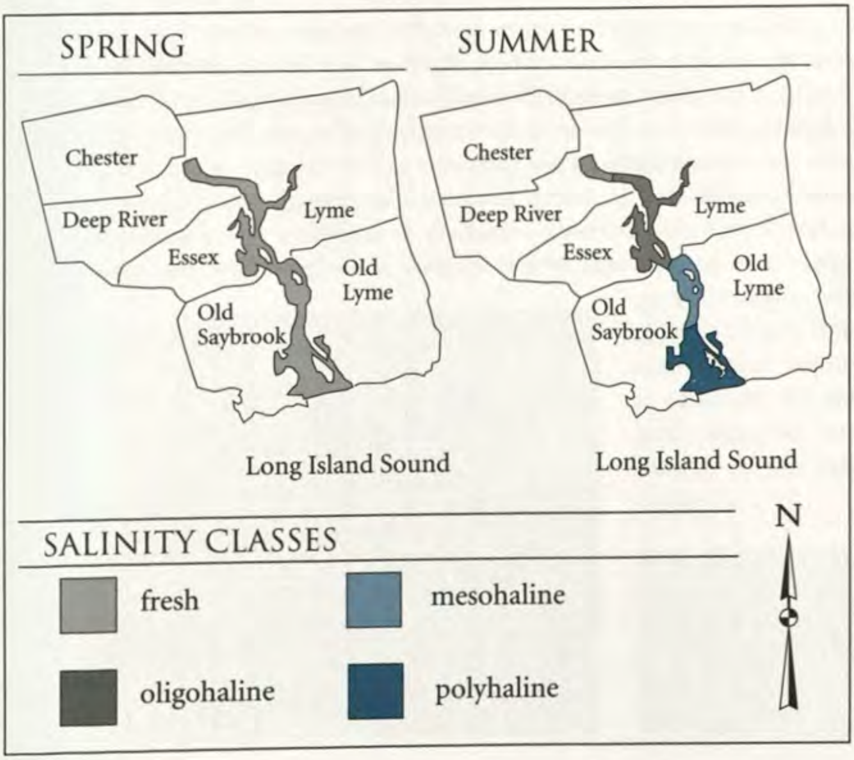
The river discharge pattern and the timing of the freshet also govern the distribution of salt water in the river. This, in turn, has a strong influence on the characteristics of emergent tidal wetlands and the distribution of plants and animals,



including rare species. Two broad classes of river water type based upon salt content are freshwater, with a salinity less than 0.5 parts per thousand (ppt) salt, and brackish water, with a salinity between 0.5 and 30 ppt. Brackish water can be further subdivided into polyhaline (18-30 ppt), mesohaline (5-18 ppt), and oligohaline (0.5-5 ppt). During spring, the freshet volumes are so great that even during high tide there is no detectable salt in surface waters (Figure 4, left). During low flow conditions in the summer, the boundary between fresh and oligohaline occurs 15 kilometers (9.3 miles) upstream (Figure 4, right). The important influence of salinity upon biological communities is explained in the Ecology chapter.

During the spring freshet, the discharge volume of freshwater is so great that the salt water boundary is moved downstream to the mouth of the river (Figure 4). Regardless of tidal stage, there is no detectable salt water in surface waters. However, seawater, which is more dense and heavier than freshwater, can be found at the bottom of the river between Great Island and Calves Island, depending upon the stage of the tide

The spring freshet salinities remain low through mid- to late-June. By August, the freshwater/saltwater boundary at the river surface has moved upstream to Deep River. This boundary migrates approximately 8 kilometers (5 miles) twice a day in concert with high and low tide. Thus the river's hydrology can be considered a hybrid, since both the tides and the spring freshet strongly influence its physical parameters.



Biological activity is synchronized with the hydrological rhythms of the river. The timing of the freshet coincides with the northward migration of waterfowl and the seaward migration of short-nosed sturgeon. As the freshet diminishes in the spring, salinity levels increase between the mouth of the river and Essex, and wetland plants begin to emerge. These plants are distributed along the river in accordance with their tolerance to salt water. The meadows of the river are largely devoid of trees and shrubs because the daily flooding of the tides means soils are too wet for most woody plants. The rhythm of the lunar cycle creates very high tides when the moon is new or full, and this high water level is responsible for the distribution of plants from low elevation to high elevation in the tidal wetlands (see Ecology chapter).

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HUMAN USES OF RIVER RESOURCES

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NATIVE AMERICANS

ABOUT 4,000 YEARS AGO, tidal waters pushed into and began flooding the lower Connecticut River valley. The resulting increases in plant and animal diversity and abundance influenced utilization of the river resources by Native Americans. Tribes known to have lived on the river include the Niantic to the south and the Wangunk in the northern part of the lower river. Later the Pequot and Mohegan benefited from the river's tremendous biological diversity. The river and its tributaries also served as important transportation corridors.

Native Americans used the living resources of the river in many ways. For example, bulrush and cat-tail from the tidal wetlands were woven for lodge coverings and mats. The tubers of bulrush, cat-tail and waterlily, among many other plants, provided important food items. Animals were hunted for food, clothing, tools, and as a source for ritual and ornamental objects. In the lower river these included waterfowl such as geese, wood duck, and loons, as well as mammals like muskrat, beaver, river otter, mink, and whitetail deer. Migratory fish, including American shad, alewife, Atlantic salmon, and sturgeon were important in the Native American diet. Nets of various sizes were used, and were weighted to different depths depending upon the target species. Sturgeon were caught at night from canoes using torches to attract the fish and cause them to turn belly-up for spearing (Figure 1).

Right: Figure 1. Native Americans utilized the river's abundant natural resources in many ways, including fishing with spears from canoes.

MARSH HAY PRODUCTION

Beginning in early colonial times, farmers ditched marsh surfaces to increase the harvest of grasses and improve access. Ditching drained the marsh and aerated the soils, and thus enhanced the production of short-meadow species such as blackgrass (*Juncus gerardi*) and salt-meadow cord-grass, (*Spartina patens*), collectively called salt hay. It has been estimated that by 1904, nearly 50% of Connecticut's salt marshes had been drained to enhance the production of salt hay. For the lower Connecticut River, examination of U.S. Coast and Geodetic Survey charts reveals that the Old Saybrook marshes at South Cove, North Cove, and Ragged Rock Creek had been ditched by 1883-85. A 1915 report from the Connecticut Agricultural Experiment Station indicates that the marshes from Old Saybrook to Lyme were valued for salt hay and were ditched to increase salt marsh hay yields. However, some of the ditches had apparently refilled, since the report stated "many old ditches if cleaned could be incorporated as part of a new mosquito control system." Today, the only marsh hay harvesting occurs at Great Meadows in Essex and Lord Cove in Lyme. The harvested grasses are not the typical salt hay grasses of the coastal salt marsh but rather a mix of tall grasses including switch grass (*Panicum virgatum*, Figure 2) and slough grass (*Spartina cynosuroides*). The rapid spread of the invasive common reed (*Phragmites australis*), with its persistent, semi-woody stems, interferes with these haying practices. The Great Meadows are occasionally set ablaze in winter to remove common reed. However, the fire only removes the dead, above-ground shoots, and the actual size of common reed colonies is increasing over time.

MOSQUITO DITCHING

Salt and brackish marshes along the coast were also recognized as areas that could produce large numbers of salt marsh mosquitoes, which are capable of flying long distances. In the early 1900s, the state of Connecticut started ditching coastal marshes to reduce breeding habitat for mosquitoes that transmitted malaria, a disease brought north by soldiers returning from the Civil War a half century before. The Connecticut River wetlands targeted for mosquito control were the brackish meadow marshes of Old Lyme, Lyme, and Old Saybrook. The first mosquito ditching occurred at Fenwick (Old Saybrook) in 1916. The Old Lyme marshes were ditched between 1928 and 1931 (Figure 3). The cat-tail marsh at Great Meadows in Essex was ditched in 1934 and 1935. Between 1936 and 1938 marshes were ditched at Ragged Rock and Ayers Creeks in Old Saybrook. Ditch patterns were laid out with string and boards, and the trenches dug with special ditching shovels.

By 1932, the Connecticut Board of Fish and Game began receiving complaints from hunters about the absence of shorebirds and waterfowl due to successful marsh-draining projects in places like Barn Island in Stonington and Great Island in Old Lyme. From 1932 to 1934 the Board experimented with the use of dynamite to create ponds on marshes in order to restore waterfowl use. By 1935, the Fish and Game Board had developed an agreement with the state's mosquito control program to install special gates in certain mosquito ditches to cause some flooding and restore

Opposite page: Figure 2. Switch grass (*Panicum virgatum*) is one of the tall grasses still harvested for salt hay in some marshes on the lower Connecticut River. (Dreyer)

This page, top: Figure 3. Aerial view of mosquito ditches in the marshes of Great Island, Old Lyme. The arrow-straight, parallel ditches contrast dramatically with the natural meandering tidal creeks. (DEP)

This page, bottom: Figure 4. Sandy material dredged from navigational channels in the river was sometimes deposited on island wetlands. This is Nott Island, between Essex and Old Lyme, in 1980.

aquatic habitat for waterfowl. The gates could also be opened as needed to drain the marsh and reduce mosquito breeding habitat. In 1937, the First Selectmen in Old Lyme protested this approach, having previously paid for the construction of ditches.

All of the brackish marshes from Essex and Lyme to the mouth of the river have been ditched. Most of the freshwater tidal marshes farther up river remain unditched, with the exception of the Cromwell and Pecausett Meadows, which were probably done for agricultural purposes rather than for mosquito control.

NAVIGATION IMPROVEMENTS

Since the 1800s, a variety of federal navigation improvements have been conducted on the river. There are approximately 20 shoals or bars between the mouth of the river and Hartford that require periodic dredging to maintain a safe channel for boat traffic. In addition to periodically dredging a channel in the mainstem of the river, an entrance channel and turning basin were dredged in Hamburg Cove around 1910, and anchorage areas were dredged in North Cove, Old Saybrook, and near Essex Island. Wetlands at Nott Island, Essex Island, and Calves Island were used as disposal locations for sandy dredged sediments (Figure 4). A pair of jetties was constructed at the mouth of the river in the early part of the 20th century; these trap sand that would have been deposited there and obstructed navigation. The westernmost jetty has allowed the adjacent beach to increase in width by about 215 meters (700 feet) in nearly 100 years.

A number of marinas have been constructed on the river over the past fifty years to accommodate the increasing popularity of recreational boating. Many are located along the main shoreline of the river, which minimizes impacts on resources and water quality. At Ragged Rock Creek, Chester Creek, and Pratt Cove, marina basins were created in tidal wetlands through dredging, an activity no longer permitted under the Tidal Wetlands Act of 1969.

COMMERCIAL AND RECREATIONAL FISHING

The Connecticut River is renowned for its bountiful fish stocks and anadromous finfish runs. One of the principal fish sought by commercial fishers was American shad, which "runs" up the river from April through June each year. During the 1800s, three principal techniques were used commercially to catch shad: sweep-nets, pounds, and drift nets. Piers consisting of a mound of rock with a vertical wooden pile in its center were constructed a short distance from shore. One end of a sweep-net was fastened to the pile, and the net played out from a boat. The net was then swept in a circle around the pile and returned to the pier to haul in shad. Sweep-nets were nearly 600 meters (2,000 feet) long and 9 meters (30 feet) deep. Pound nets were deployed at five locations between Fenwick and Lynde Points, Old Saybrook. While pound nets were also used east of the river, by the late 1800s this technique was abandoned due to diminishing fish stocks. Gill nets or drift nets measuring nearly 300 meters (1,000 feet) in length and 7.5 meters (25 feet) in depth were placed two miles upriver and allowed to drift downstream with the currents. Gill nets are still used today.

Recreational fishing is currently an important river industry, thanks to the restoration of water quality over the last four decades. Fishing for striped bass, bluefish, and summer flounder is popular at the mouth of the river. In late summer, as salt water reaches its maximum upstream position, bluefish are frequently found in abundance in Hamburg Cove. In tidal freshwaters, smallmouth and largemouth bass fishing is popular. The Connecticut Department of Environmental Protection raises northern pike at Haddam Neck and releases them throughout the state, including in the Connecticut River. In the last decade, the river has attracted national bass tournaments based at Hartford.

TOURISM

The Connecticut River, and the quaint towns along its shore, have become increasingly popular vacation and tourist destinations. Ecotourism is a new and fast-growing industry both locally and internationally. One of the first and most popular local attractions is the Essex steam train, which leaves from the Essex train station and heads north along the west side of the river through the scenic towns of Deep River and Chester. Riders disembark in Haddam and board a steamship for the return voy-

Figure 5. Tourists on a steam train/steam boat ride make their way from Haddam to Essex. (DEP)

age (Figure 5). This is a particularly popular tour during fall foliage season. Winter cruises provide visitors with an opportunity to see seals and eagles. The Connecticut River now boasts one of the largest winter concentrations of bald eagles, a phenomenon marked by the annual Essex Eagle Festival (Figure 6).

Another popular activity is canoeing or kayaking along the riverbanks and through the marshes (Figure 7). These quiet forms of transportation allow one to get quite close to birds and other wildlife, and provide an inspiring perspective of the river impossible to gain from land.

Top: Figure 6. The federally threatened Bald Eagle is an increasingly common sight on the river. (Fusco)

Bottom: Figure 7. Kayaking along a freshwater tidal marsh. Low impact ecoturism is increasingly popular. (Rozsa)

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ECOLOGY OF THE LOWER CONNECTICUT RIVER: PLANTS, ANIMALS, AND THEIR HABITATS

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THE BIOLOGICAL COMMUNITIES along the 58-kilometer (36-mile) segment from Portland/Cromwell to Long Island Sound are unique for the entire Connecticut River watershed. Within this reach of the river there are numerous shallow coves and marshes that are separated from the mainstem by bars and levees. Only here are tides the dominant factor organizing the distribution of plants and animals. Farther upstream, riverine processes dominate and there are few coves.

The Ramsar Convention defines wetlands as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tides does not exceed six meters." The Convention provides that wetlands "may incorporate riparian and coastal zones adjacent to the wetlands, and islands …" In addition to the emergent wetlands and tidal waters, the area of the Connecticut River designated under this convention includes coastal barriers, several islands such as Selden's Neck and floodplain levees and forests.

The lower river can be divided into two major ecological systems, the estuary and the tidal river. Estuaries, by definition, include waters where salt and freshwater mix, and the upstream limit of an estuary is defined by a salt content or salinity of 0.5 ppt (parts per thousand) or greater. For plants and animals living in surface waters and in the intertidal zones of the river, the boundary of the estuary lies above Great Meadows in Essex, approximately 13 kilometers (5 miles) upstream from the Sound. The tidal river system extends from Essex to Portland/Cromwell, where the surface waters are fresh and devoid of salt water influence.

ESTUARINE SYSTEM

THE PREDOMINANT habitats of the estuarine system are brackish emergent wetlands, submerged aquatic vegetation and brackish waters from the mouth of the river up to and including Essex and Lyme. Two biologically significant coastal barriers form the southern boundary of the Connecticut River estuary.

COASTAL BARRIERS

TWO COASTAL BARRIERS, Griswold Point in Old Lyme (Figure 1) and Lynde Point in Old Saybrook, mark the boundary between the river and Long Island Sound These are a complex of beach and sand dunes that are one of the most uncommon coastal habitats in the Sound.

The beach is that zone between mean low water and the base of the dune corresponding to the highest reaches of annual storm tides. Here "soils" are sandy, extremely well drained and subject to the vagaries of wave action and the deposition of salt spray. In this inhospitable environment, no vegetation is present except at the highest elevations. Where plants do grow, they are annuals that possess a variety of defense mechanisms to combat the toxic effects of sea salts. The primary species are sea rocket (*Cakile edentula*), pigweed (*Chenopodium berlandieri* var. *macrocalycium*), seaside spurge (*Euphorbia polygonifolia*) and Russian thistle (*Salsola tragus*). These plants overwinter as seeds, and as winter wave action removes and redistributes sand, it also redistributes these seeds. Thus the location and extent of these plants varies from year to year. The seeds tend to accumulate in what researchers call the "annual wrackline," which corresponds with the annual average highest reach of the tides in the fall and winter.

Animals also find this sandy zone inhospitable. The federally threatened piping plover (*Charadrius melodus*) and the state threatened least tern (*Sterna antillarum*) are birds that have developed adaptations to complete a portion of their life cycle on the open beach. Their nests are constructed as minor depressions in the sand. Terns usually deposit two eggs, and plovers four. Plovers line the depression with shell fragments. The eggs of both species are cryptically colored to match the sandy/pebbly background and thus provide camouflage against predators, especially birds such as gulls. Unfortunately, this makes it difficult for humans on foot or in vehicles to avoid these nearly invisible nests. Beach nest sites are also subject to destruction by spring and summer tidal floods.

A network of volunteer conservationists is often present on beaches where these birds nest in order to protect them from human disturbance. The eggs require heat regulation by the adult, providing warmth on cold days and cool nights and protection from the heat of the sun during the day. Regular disturbance of the adults during nesting can cause heat stress or death of the embryos in the eggs.

Shorebirds can frequently be observed foraging along the water's edge for small insects and beach shrimp called amphipods. The most common beach shorebirds are the sanderling (*Calidris alba*) and semipalmated sandpiper (*C. pusilla*). For more on bird life, see the Birds of the Lower Connecticut River chapter in this bulletin.

The beach is also the primary source of wind-blown, or aeolian, sand that creates and maintains the adjacent sand dunes. The magnitude and height of sand dunes are directly related to the width of the beach. Beaches in Connecticut are narrow as a result of low wave energy, and so the dunes are also small, often less than 30 meters (100 feet) in width and 2 meters (6 feet) in height. Dune vegetation is characteristically a coastal grassland community dominated by American beachgrass (*Ammophila breviligulata*). Few plants are adapted to constant burial by sand, but beachgrass deals with being covered by elongating its shoots. Sand deposition is greatest on the seaward or fore-slope of the dune, where beachgrass is the premier plant, along with a few associates such as seaside goldenrod (*Solidago sempervirens*) and beach pea (*Lathyrus maritimus*).

On the backslope dune, sand deposition rates decrease and substrate stability increases, which promote an increase in plant species diversity. Beachgrass is still the

Figure 1. Aerial photographs of Griswold Point, Old Lyme in 1990 (above) and 2000 (below). The year 2000 photograph shows the ever-widening breach in the middle of the coastal barrier spit. In both images the mouth of the Connecticut River is at the extreme left and the southern end of Great Island is in the upper left. (DEP)

Figure 2. Professor R. S. Warren, Connecticut College, in brackish meadow vegetation on Great Island, Old Lyme, at the mouth of the Connecticut River. (Rozsa)

dominant plant. Associates include evening primrose (*Oenothera parviflora*), a sedge (*Carex silicea*), soapwort (*Saponaria officinalis*), pinweed (*Lechea maritima*), and Gray's sedge (*Cyperus grayii*). This "sea of grass" is sometimes interrupted by patches of open sand deposited by storm overwash, or by shrubland. The predominant shrubs on the beach are a naturalized Japanese rose species (*Rosa rugosa*), bayberry (*Myrica pensylvanica*), and beach plum (*Prunus maritima*).

Griswold Point is a typical linear coastal barrier spit, connected to the upland at one end, with a narrow beach along the sound and a single primary dune behind. In contrast to the linear form of Griswold Point, Lynde Point has a very different character due to the construction of a long, stone breakwater perpendicular to the beach. The breakwater intercepts sand that is pushed eastward by wave action, which in turn causes the beach to grow in a seaward direction. This widening of the beach has created an extensive area of level sand behind the dune. This is termed a backbarrier flat and represents one of the least common habitat types associated with coastal barriers. Protection from waves, low aeolian deposition rates and increased soil stability allow the development of extensive shrubland and increases in plant species diversity. At one time, native prickly pear cactus (*Opuntia humisifolia*) was seen here.

In 1994, a major winter nor'easter breached Griswold Point and formed a small narrow inlet. This inlet has expanded, and today it is 450 meters (1500 feet) across (Figure 1). What was formerly the western end of the peninsula is migrating in a northwesterly direction, and is expected to eventually attach to Great Island. The same process occurred over 100 years ago, and the only remnants of what was once called Poverty Island are the narrow sand ridges on Great Island. In time, what is left of Griswold Point will elongate and create a more complex topography in the form of a series of oblique dune ridges.

BRACKISH EMERGENT WETLANDS

ONLY SEVERAL hundred feet from the salty waters of Long Island Sound, the Great Island tidal wetlands perfectly match the first published description of Connecticut brackish meadow marshes written in 1920 by the prominent Yale University plant ecologist Dr. George Nichols (Figure 2). In fact, from the southern to northern end of this island, one can observe the range in salinity and plant community variety as described by Nichols:

> Locally over considerable areas the salt meadow grass, alkali grass, and black grass, together with most of their associates in more saline situations, may be quite as prominent here as in salt meadows. Certain of the salt meadow species, particularly *Triglochin* and *Solidago*, are even commoner in brackish meadows, while… the two species *Salicornia* and the *Limonium*, are perceptibly less frequent here. There is a marked tendency, however, for the salt meadow grasses to give way in brackish meadows to other grasses of grass-like forms, notably *Agrostis alba maritima*, *Eleocharis palustris*, and *E. rostellata*; and, especially in the fresher or higher parts of the meadows, these latter may predominate.

The absence of salt marsh in the Connecticut River can be explained by the strength of the spring freshet, which causes a significant reduction of surface water salinity during spring and early summer, the time when soil salinity concentrations have their greatest effect upon vegetation. In these marshes another indicator of low soil salinity is the distinctive tall and robust growth form of black grass (*Juncus gerardii*). The brackish nature of this marsh is also evident in the vegetation of the low marsh zone, located along the borders of the island and tidal creeks. Smooth cord-grass (*Spartina alterniflora*) is the dominant plant, but growing at the base of this grass are several diminutive plants including spikerush (*Eleocharis parvula*), eastern lilaeopsis (*Lilaeopsis chinensis*), and mudwort (*Limosella subulata*). *Lilaeopsis*, a relative of Queen Anne's lace, produces a simple flower stalk only 5 centimeters (2 inches) high from a whorl of equally short, segmented leaves. Across from the Great Island boat launch ramp, smooth cord-grass gives way to a taller related grass known as big cord-grass (*Spartina cynosuroides*). This relatively rare plant community is rapidly being displaced by the tall, invasive common reed (*Phragmites australis*, see Management Issues chapter).

At the northern end of this island and in the meadows of Ragged Rock Creek, Upper Island, and Calves Island, the meadows are dominated by species such as bentgrass (*Agrostis stolonifera*), spike rush (*Eleocharis rostellata* and *E. palustris*), common threesquare (*Scirpus pungens*), straw sedge (*Carex straminea*), red fescue (*Festuca rubra*), mock bishop-weed (*Ptiliminum capillaceum*), New York aster (*Aster novi-belgii*), salt marsh fleabane (*Pluchea purpurascens*), and Olney-threesquare (*Scirpus americanus*). Only 30 years ago, short meadow vegetation was dominant throughout Great Island. This is no longer the case as the invasion by common reed continues.

From the north end of Great Island to Lords Cove, the short meadow vegetation is punctated by bulrushes ranging from the short common threesquare to the taller Olney-threesquare and saltmarsh-bulrush (*Scirpus robustus*). The latter rush is replaced by the state-listed species of special concern, *Scirpus cylindricus*, in upstream marshes where soil salinity diminishes.

TIDAL WETLANDS – FUNCTIONS & VALUES

The amount of plant material produced annually by an ecosystem is called primary productivity. Tidal wetlands rank among the systems with the highest productivity of any in the world. They rival tropical rain forests in amount of plant material, or biomass, produced each year. Relative to salt marshes, the brackish and tidal-fresh marshes of the river support two and eight times more plant matter, respectively. These marshes are also noted for their critical habitat support for rare species, including nine species of birds and eight species of plants. Numerous invertebrates – insects, snails and amphipods among others – live on the marsh and marsh soils and convert plant material into energy that supports estuarine food chains. The killifish (*Fundulus* spp., Figure 3), an overlooked and seemingly minor estuarine organism, is an essential underpinning of the marsh-estuarine food chain. As the marsh is flooded, killifish forage among the emergent plants for snails and amphipods and leave with full guts on the ebbing tide. In the estuary, killifish are prey for numerous finfish, many of which are of recreational or commercial significance, such as bluefish, striped bass, and fluke.

Figure 3. Small fish, including killifish (*Fundulus* sp.) and Atlantic silversides (*Menidia menidia*) shown in this net, live in brackish tidal creeks and form an important link in the marsh-estuary foodchain. (Fell).

Figure 4. Brackish meadows with narrow-leaved cat-tail (*Typha angustifolia*) and common reed (*Phragmites australis*) in Old Saybrook. (Niering, 1974)

Figure 5. Wild rose mallow (*Hibiscus moscheutos*), a tall and showy wildflower of the the cat-tail dominated brackish meadows of the lower river. (Rozsa)

The last major plant community complex of the brackish emergent marshes is characterized by narrow-leaved cat-tail (*Typha angustifolia*), which makes its first appearance as scattered colonies on the northern end of Great Island (Figure 4). A short distance upstream at Lord Cove, cat-tail becomes the dominant plant and grows to an average height of 1.5 meters (5 feet). This cat-tail prefers alkaline waters and its presence in brackish marshes is likely related to the neutral to alkaline pH conditions of the soil. A notable associate of the cat-tail is the wild rose mallow (*Hibiscus moscheutos*), which bears large, pink flowers about 15 centimeters (6 inches) wide on plants up to 2 meters (6.5 feet) tall (Figure 5).

Great Meadows in Essex supports a tall reed plant community, seen nowhere else on the river, dominated by the hybrid cat-tail (*Typha x glauca*). This cat-tail can grow to heights of 2.5-3.3 meters (8-10 feet). Common reed and wild rose mallow are often co-dominants, and the former may occur in dense, single species stands. Associates include marsh fern (*Thelypteris palustris*), spike rush (*Eleocharis smallii*), arrow arum (*Peltandra virginica*), purple loosestrife (*Lythrum salicaria*), bur-marigold (*Bidens cernua*), mermaid weed (*Proserpinaca palustris*), and dotted smartweed (*Polygonum* punctatum). In the drier upland borders, freshwater cord-grass (*Spartina pectinata*) and switch grass (*Panicum virgatum*) are often dominant plants. The low marsh is composed principally of common threesquare, and associates include salt marsh hemp (*Amaranthus cannabinus*), dotted smartweed, and sweet flag (*Acorus calamus*). Non-native, invasive plants include purple loosestrife, the false indigo shrub (*Amorpha fruticosa*) and, especially, common reed (Figure 6).

In the protected shallow subtidal waters, such as the coves and tidal tributaries, a distinctive and ecologically important community of underwater rooted flowering plants develops. These beds are called submerged aquatic vegetation (SAV) (Figure 7). SAV greatly enhances productivity, provides an important food staple for waterfowl, and provides refuge for many juvenile fish. This last function can be observed in the fall, when juvenile herring are returning to the Sound and seek refuge in the SAV from predators such as striped bass and bluefish. The dominant species in mesohaline waters (brackish with 5-18 ppt salt) are widgeon grass (*Ruppia maritima*) and horned pondweed (*Zannichellia palustris* var. *major*). In the oligohaline zone (brackish water with 0.5-5 ppt salt), the dominant species are tapegrass (*Vallisneria americana*), common water-weed (*Elodea canadensis*), and horned pondweed (*Zannichellia palustris*). In a recent study, non-native, invasive European water-milfoil (*Myriophyllum spicatum*) exceeded 70% coverage in less than 8% of the SAV sampling locations, and is not currently considered a threat.

Within the estuarine system of the lower Connecticut River there are several general types of contiguous habitats for animals. The river-marsh edge, intertidal creeks, regularly flooded low marsh, and irregularly flooded high marsh are habitats for many species of animals. Where specific animals are found varies with tidal phase, time of day, seasons, and/or life stage.

A rich diversity of invertebrates may be found within the small intertidal creeks that penetrate deeply into the marshes. Among the most prominent are green crabs (*Carcinus maenas*), blue crabs (*Callinectes sapidus*), and mud crabs (*Rithropanopeus harrisii*). They are present in the brackish creeks and sometimes in water that is nearly fresh. Grass shrimp (*Palaemonetes pugio*) and an amphipod (*Gammarus tigrinus*) are widely distributed in the brackish marsh creeks, but are most abundant where the salinity is relatively high. Another amphipod (*Leptocheirus plumulosus*) and red midge larvae (primarily *Chironomus* spp.) tend to be somewhat more abundant at lower salinities. Also present in the brackish creeks are other amphipods, an anthurid isopod (*Cyathura polita*), hydrobiid snails, and various annelids including *Hobsonia florida.*

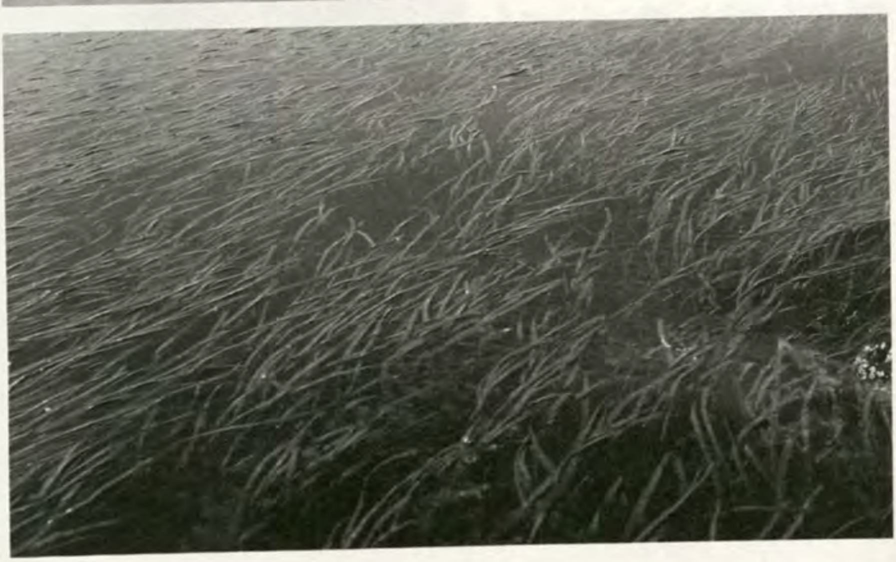
In the brackish low marsh, fiddler crabs (primarily *Uca minax*) are often the most conspicuous invertebrates. Ribbed mussels (*Guekensia demissa*) are also present near the mouth of the Connecticut River.

Marsh amphipods (*Orchestia grillus*), marsh isopods (*Philoscia vittata*), fiddler crabs, and marsh snails (*Melampus bidentatus* and *Succinea* sp., Figure 8) are among

Below left: Figure 6. Aerial view of Great Meadows in Essex, a brackish marsh dominated by *Typha x glauca.* the colonies of invasive common reed are indicated by the letter "P." North is to the right in this photo.

Below right: Figure 7. Submerged aquatic vegetation (SAV), in this case entirely tape grass (*Vallisneria americana*), forms important communities in the river. (Rozsa)

Left: Figure 8. Characteristic brackish high marsh invertebrates include the snails *Melampus bidentatus* (left) and *Succinea* sp. (right). (Fell)



the characteristic high marsh invertebrates in brackish regions of the Connecticut River system. *Melampus* are typically most abundant in regions of highest salinity, whereas *Succinea* is most abundant near the opposite end of the salinity range. Another snail, *Stagnicola catascopium*, may occur where salinities are relatively low, as well as in freshwater tidal marshes. On both the brackish and freshwater tidal marshes, spiders and larval and adult insects are important components of the invertebrate communities. Many of these invertebrates are a source of food for other animals.

More than 20 species of fish have been collected in intertidal creeks that penetrate the marshes of the lower Connecticut River (Figure 3). During the warmer months of the year, as many as 15 species of fish may be found in a single creek, but not all at the same time. The more abundant species include the common mummichog (*Fundulus heteroclitus*), striped killifish (*Fundulus majalis*), banded killifish (*Fundulus diaphanus*), spottail shiner (*Notropis hudsonius*), fourspine stickleback (*Apeltes quadracus*), Atlantic silverside (*Menidia menidia*), white perch (*Morone americana*), pumpkinseed (*Lepomis gibbosus*), and young American shad (*Alosa sapidissima*). Others such as small bluefish (*Pomatomus saltatrix*), American eel (*Anguilla rostrata*), yellow perch (*Perca flavescens*), and crevalle jack (*Caranx hippos*) occur in smaller numbers. Many of these fishes are widely distributed along the salinity gradient. Mummichogs are found in waters ranging in salinity from freshwater to 32 ppt. On the other hand, striped killifish are found primarily in saline water, whereas banded killifish occur in low salinity and fresh water. Some additional species of fish that are found in the subtidal creek/river habitats at the edge of the marsh include striped bass (*Morone saxatilis*) and Atlantic menhaden (*Brevoortia tyrannus*).

Figure 9. Professor Paul Fell, Connecticut College, holding a clear plastic "Breder" trap. These are staked out on the marsh surface to sample fish swimming on top of the marsh during very high (spring) tides. (Rozsa)

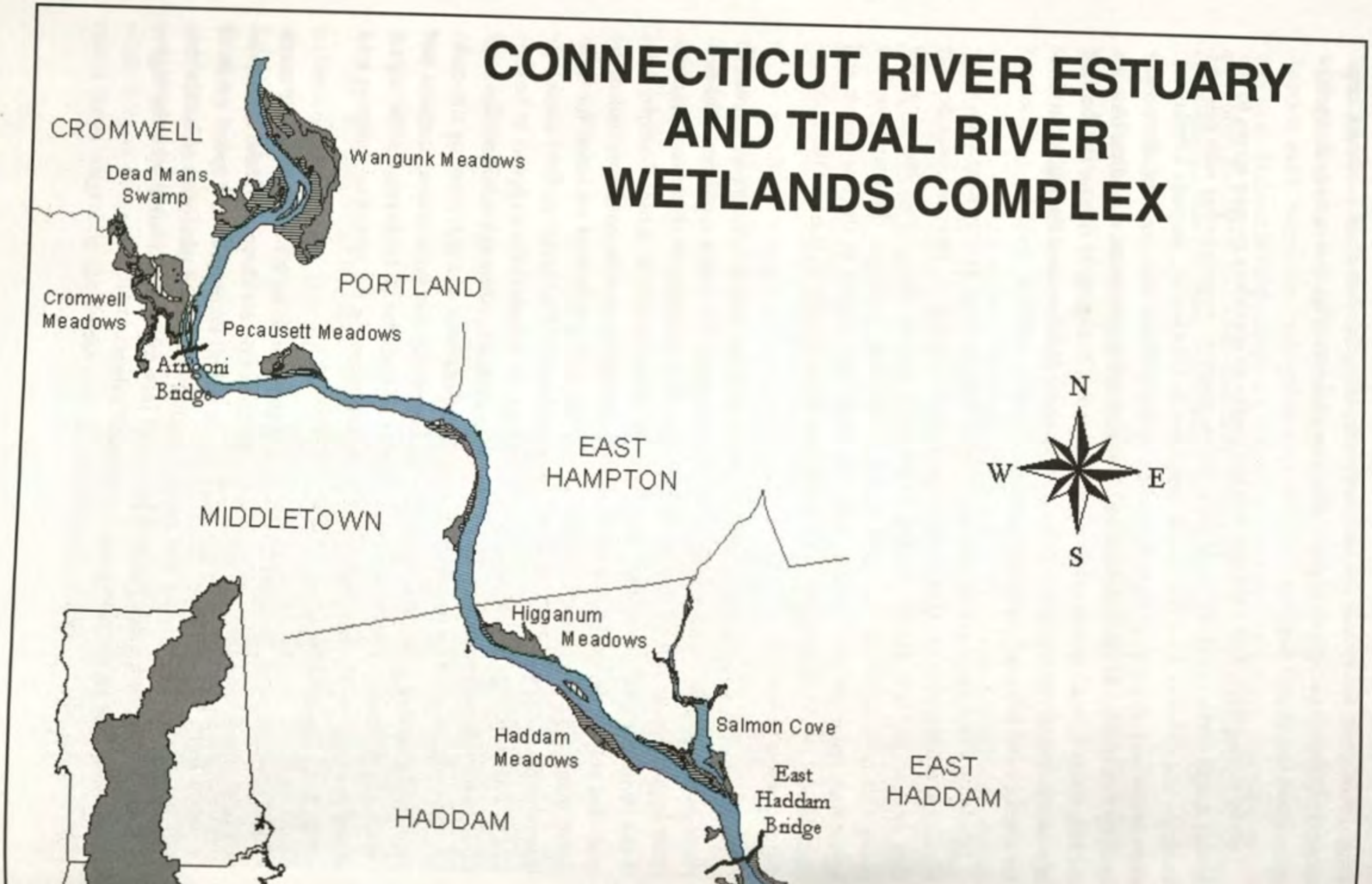
The mummichog is often the numerically dominant fish of the intertidal creeks. Together with other fishes, it moves into the creeks on the flooding tide and back out of them on the ebbing tide. Frequently its gut contains substantially more food when it leaves the creeks than when it enters them, suggesting the creeks are important foraging areas. The mummichog feeds heavily on amphipods in regions of high salinity but, at low salinity and freshwater sites, this fish often consumes large amounts of filamentous green algae. Other components of its diet include midge larvae, isopods, snails, and detritus.

During spring tides, fish may also use the creeks as corridors to gain access to the flooded marsh surface (Figure 9). At these times, mummichogs together with eels and fourspine sticklebacks feed on marsh amphipods (*Orchestia*), isopods (*Philoscia*), snails (especially *Succinea*), insects, and/or spiders. These fish, in turn, are preyed upon by fish species of recreational and commercial importance, including bluefish and striped bass, wading and other birds, and crabs. Foraging by fish on the flooded high marsh appears to represent a direct food-chain link between the highly productive marshes and adjacent estuarine waters.

In addition to foraging, fish may use tidal marsh systems as spawning sites, nurseries for juveniles, and/or refuges from open water predators. Mummichogs deposit their eggs in the low marsh during night high spring tides. Upon hatching, the young fish may spend six to eight weeks in shallow pools on the marsh surface before they enter the tidal creeks. Atlantic silversides spawn in the low marsh and shallow tidal creeks during day high tides. For more details on fish, see the Fisheries chapter in this bulletin.

During the last forty to fifty years, common reed has been displacing typical marsh plants in the tidal wetlands of the lower Connecticut River at a rapid rate, and currently large areas are dominated by this invader. The macroinvertebrate communities of the common reed-dominated wetlands are often similar to those of nearby wetlands that are largely free of this plant. This fact suggests that the common reed-dominated marshes provide suitable physical habitat and usable food resources for these invertebrates, many of which are detritus/algae feeders. Furthermore, food consumption by mummichogs in intertidal creeks and on the marsh surface appears to be similar in common reed-dominated and reed-free wetlands. Although initial studies indicate that with respect to macroinvertebrate populations and fish foraging the common reed marshes may be functioning in essentially the same way as marshes not invaded by this plant, further research should be undertaken to determine the impact of this ongoing vegetation change. More information on the spread of common reed will be found in the Management Issues chapter.

The diamondback terrapin (*Malaclemys terrapin terrapin*) is an estuarine turtle that prefers brackish waters (Figure 2 in the Trust Species chapter). These turtles can be found from the mouth of the river up to Essex. Diamondbacks spend much of their time in the tidal creeks and coves foraging upon mollusks, other invertebrates, and carrion. Nesting takes place in June and July, often coincidental with the higher spring tides. The incubation period averages 75 days.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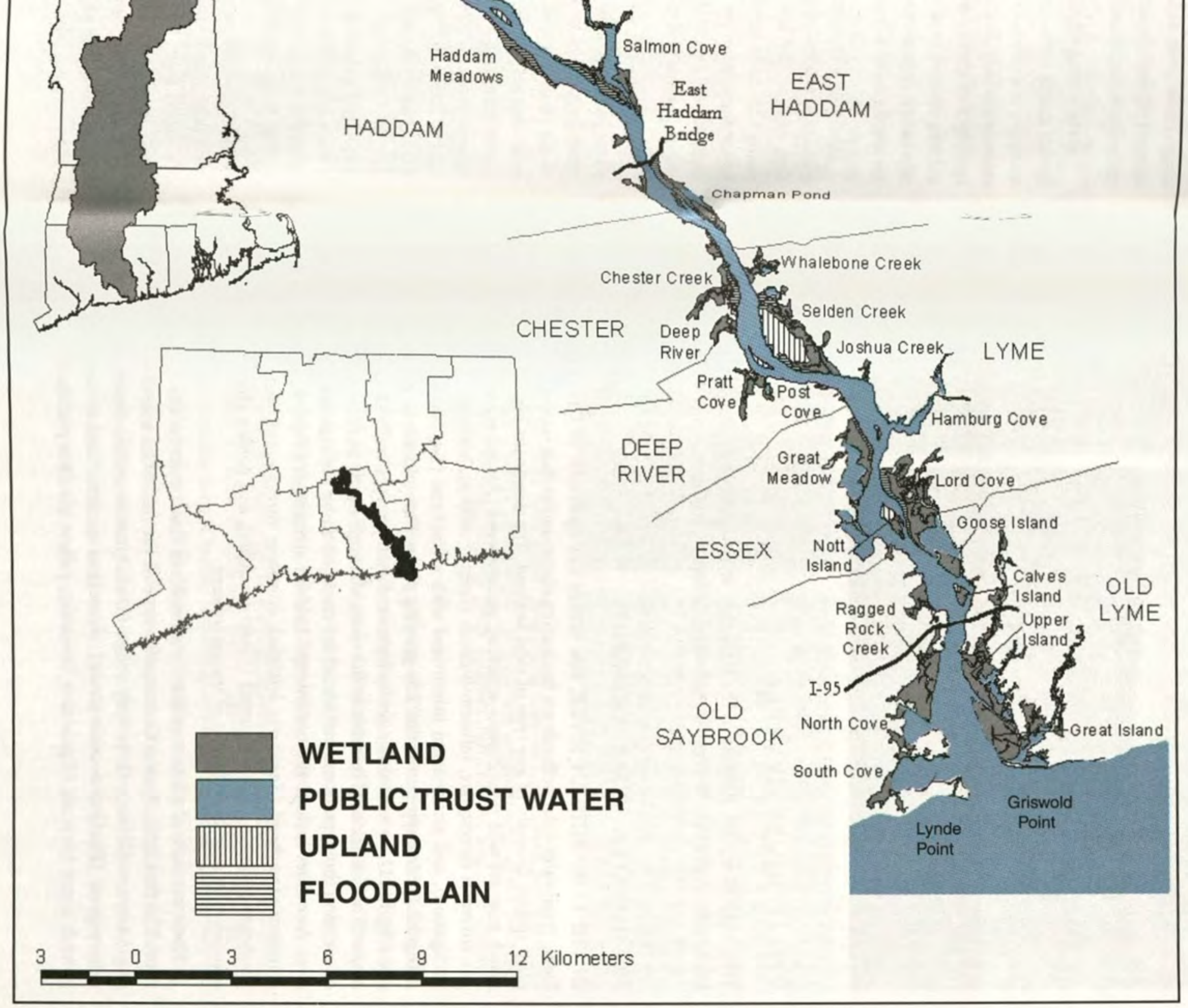
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Pratt Cove
Post Cove
Hamburg Cove
DEEP RIVER
Great Meadow
Lord Cove
Goose Island
ESSEX
Nott Island
Calves Island
OLD LYME
Ragged Rock Creek
Upper Island
I-95
OLD SAYBROOK
North Cove
Great Island
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TIDAL RIVER SYSTEM

THE MAJOR aquatic habitats of the tidal river system include freshwater-tidal wetlands, submerged aquatic vegetation, floodplain forests, and open water complexes.

FRESHWATER-TIDAL WETLANDS

IN THE CONNECTICUT RIVER, this system lies upstream of Great Meadows, Essex. Freshwater-tidal wetlands are fascinating communities that support the highest plant species diversity of any type of tidal wetland. The dominant plants in the low marsh zone are wild rice (*Zizania aquatica*), pickerelweed (*Pontederia cordata*, Figure 10), common threesquare, softstem-bulrush (*Scirpus validus*), bullhead-lily (*Nuphar variegatum*), and arrow-arum intermixed with arrowhead (*Sagittaria* spp.), bur-marigolds (*Bidens* spp.), and other low-growing plants. Pure and mixed stands of wild rice (Figure 11), an annual that grows from seed each year, generally characterize the majority of riverine tidal marshes in the coves, although nearly pure or mixed stands of common threesquare and arrowhead are common along the exposed shore of the river. Associates include the uncommon Hudson arrowhead (*Sagittaria subulata*), common arrowhead (*Sagittaria latifolia*), common threesquare, water purslane (*Ludwigia palustris*), false pimpernel (*Lindernia dubia*), and golden club (*Orontium aquaticum*), a state-listed species of special concern

There are several plant community complexes that occur in the high marsh zone. The first is the Acorus Community-type of the mid-tidal marsh with sweet flag (*Acorus calamus*), three-way sedge (*Dulichium arundinacium*), and reed canary-grass (*Phalaris arundinaceum*). Associates include tussock sedge (*Carex stricta*), water horsetail (*Equisetum fluviatile*), yellow iris (*Iris pseudacorus*), pur-

Above left: Figure 10. A freshwater tidal emergent marsh of pickerel weed (*Pontederia cordata*). (Rozsa)

Above center: Figure 11. A fresh water tidal low marsh dominated by the annual plant wild rice (*Zizania aquatica*). (Rozsa)

Above right: Figure 12. A freshwater tidal marsh of arrow-arum (*Peltandra virginica*) at low tide in Portland, Connecticut. (Niering)

Left: Figure 13. Cat-tail (*Typha*) flowering in freshwater tidal wetland. (Collins)

ple loosestrife, spotted jewelweed (*Impatiens capensis*), common bur-marigold (*Bidens frondosa*), water smartweed (*Polyganum amphibium*), giant bur-reed (*Sparganium eurycarpum*), swamp dock (*Rumex verticillata*), and rice cutgrass (*Leersia oryzoides*).

In the Peltandra Community-type, in addition to arrow-arum (*Peltandra virginica*) a number of species may dominate, including common cat-tail (*Typha latifolia*), river bulrush (*Scirpus fluviatilis*), and common reed (Figure 12 & 13). This type occurs on regularly flooded marshes, and community associates include sedges, rice cutgrass, common bur-marigold, and blue flag (*Iris versicolor*).

The Onoclea Community-type of the high marsh is the most floristically diverse of the freshwater wetland community types. Characteristic and often dominant plants include sensitive fern (*Onoclea sensibilis*), common cat-tail, and river bulrush. Associates include marsh fern (*Thelypteris palustris*), ground-nut (*Apios americana*), clearweed (*Pilea pumila*), cut-leaved water-horehound (*Lycopus americana*), arrow-leaved tearthumb (*Polygonum sagittatum*), spotted Joe-pye-weed (*Eupatorium maculatum*), marsh bellflower (*Campanula aparinoides*), and tall meadow-rue (*Thalictrum polygamum*).

Above: Figure 14. Aerial view of a floodplain forest along a levee, between the Connecticut River and freshwater tidal marsh. (DEP)

Below right: Figure 15. Floodplain forest of silver maple (*Acer saccharinum*) with the spring high flood level marks clearly evident on the tree trunks. (Niering)

A very high diversity of plants, often over 20 species, occurs in the submerged aquatic vegetation (SAV) of the tidal river system. The dominant plants, listed in descending order of abundance, are tapegrass, common water-weed, coontail (*Ceratophyllum demersum*), and European water-milfoil. In a recent study conducted by The Nature Conservancy, European water-milfoil was present in 25% of samples, and only dominant in 4%. Although categorized by ecologists as an invasive exotic, it does not currently appear to be a nuisance aquatic plant in the lower river.

To a large extent, the animals of freshwater tidal marshes are different from those of brackish tidal marshes. Common macroinvertebrates of the high marsh include limacid slugs (*Agriolimaz laevis*), succineid snails (*Oxyloma* spp.), earthworms (Lumbricids and Megascolecids), harvestmen (Opilionids), spiders, especially wolf (Lycosid), and insects such as ground beetles (Carabid) and fly larvae (Dipteran). A small snail (*Pomatiopsis* sp.) may be abundant where the dominant plant cover is cattail, bulrush, sedge or common reed. Knowldege of the macroinvertebrate communities of freshwater and brackish tidal marshes is far from complete, and more studies are needed to better understand the animals and their roles in these important systems.

Some of the fishes of the brackish tidal creeks are also present in the freshwater tidal creeks. These include the common mummichog, banded killifish, yellow perch, and pumpkinseed. The mummichog tends to be less abundant and the pumpkinseed more so in the freshwater systems. Other species that typically occur only in freshwater systems are largemouth bass (*Micropterus salmloides*), carp (*Cyprinus carpio*), and redbreast sunfish (*Lepomis auritus*).

FLOODPLAIN FORESTS

AS NOTED IN the hydrology chapter, the height of the spring freshet is greatest upstream of the geographic focus of this bulletin. In the region from Cromwell south to Essex, floodplain forests are largely confined to levees, pendent bars, and narrow zones adjacent to the tidal wetlands and cove shorelines (Figure 14). Many of the larger levees have been cleared for agriculture or open space (e.g., Haddam Meadows and Great Meadows), while the narrow bars still support floodplain forest.

Floodplain levees parallel the Connecticut River shoreline and, where coves are present, act as wave barriers creating sheltered environments conducive to the formation of tidal wetlands and submerged aquatic vegetation beds. The levee is often elevated above the zone of river scour, and receives active over-bank deposition of fine sands and silts during floods. Several characteristic trees occur, including red maple (*Acer rubrum*), green ash (*Fraxinus pennsylvanica*), bitternut hickory (*Carya cordiformis*), American elm (*Ulmus americana*), butternut (*Juglans cinerea*), and, occasionally, red oak (*Quercus rubra*). The shrub layer is sparse, consisting of spicebush (*Lindera benzoin*), silky dogwood (*Cornus sericea/obliqua*), alder (*Alnus rugosa/serrulata*), northern arrow-wood (*Viburnum recognitum*), and an occasional black willow (*Salix nigra*). The herbaceous layer is often lush and diverse, and is characterized by

species such as jack-in-the pulpit (*Arisaema triphyllum*), a sedge (*Carex bromoides*), wood-reedgrass (*Cinna arundinaacea*), terrell grass (*Elymus virginicus*), white avens (*Geum canadense*), goldenrod (*Solidago canadensis* and *S. altissima*), and jumpseed (*Tovara virginiana*).

The inner floodplain forests are the low-lying lands that lie adjacent to the wetlands or the shorelines of coves and are inundated at least during the spring freshet. In the quiescent waters behind the levees, floodwaters deposit very fine and fertile sands and silts. Although similar in gross appearance to the vegetation on the levees, the flora of the inner floodplain is generally less diverse and has a dominant ground cover of sensitive fern (*Onoclea sensibilis*). Characteristic species include red maple, silver maple (*Acer saccharinum*), green ash, and American elm in the tree canopy (Figure 15). The shrub layer is predominantly silky dogwood, northern arrow-wood, spicebush, and alder. A rich ground layer is typical, with sensitive fern, false nettle (*Boehmeria cylindrica*), sedges (*Carex crinita/bromoides, C. intumescens*, and *C. stricta*), hog peanut (*Amphicarpa bracteata*), ground nut (*Apios americana*), wood reedgrass, richweed (*Pilea pumila*), lady fern (*Athyrium felix-femina*), white avens, wood-nettle (*Laportea canadensis*), and other herbs.

In areas such as Haddam Neck and Higganum Meadows, the inner floodplain grades imperceptibly into a tidal swamp. Regular inundation by tidal water keeps the soil saturated, and here woodlands are dominated by scattered red maple and green ash trees. The open canopy allows better light penetration, resulting in the formation of dense patches of shrubs such as alders, buttonbush (*Cephalanthus occidentalis*), silky dogwood, willows, winterberry (*Ilex veticillata*), and swamp rose (*Rosa palustris*). In wetter areas, open marsh, similar to the adjacent tidal marsh, forms under the open canopy. Common herbaceous species include giant bur-reed, wool-grass (*Scirpus cyperinus*), smartweed (*Polygonum* sp.), false mermaid-weed, tussock sedge (*Carex stricta*), marsh fern (*Thelypteris palustris*), false nettle, common arrow-head, arrow-arum, beggers-tick (*Bidens* spp.), and spike-rush (*Eleocharis* sp.).

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BIRDS OF THE LOWER CONNECTICUT RIVER

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THE LOWER CONNECTICUT RIVER VALLEY, a relatively unfragmented landscape of forests, tidal marshes, mud flats, and open water, supports an incredible variety of bird life throughout the year. The brackish and freshwater tidal marshes are particularly important breeding areas for many kinds of birds, including several rare species. The marshes, mudflats, pools, and shallow waters attract herons, gulls, terns, ducks, and other species that use these habitats for foraging, resting, and protection from predators, though they may breed elsewhere. The lower Connecticut River valley is also an important movement corridor for migratory birds, especially waterfowl, rails, songbirds, and raptors, which use this area each year during the spring and fall migration periods as a pathway north or south en route to breeding or wintering grounds. In the winter, the river and its coves provide critical habitat for bald eagles, several species of hawks, and abundant waterfowl. Overall, the area is characterized by a high concentration of rare species and by an impressive level of species diversity.

WATERFOWL

The lower Connecticut River supports abundant waterfowl in all seasons, a factor that was critical in the river's designation as a wetland of international importance (see Introduction). In order to assess populations, the Connecticut Department of Environmental Protection (CTDEP) conducts an annual midwinter waterfowl survey that includes the lower Connecticut River from Salmon River Cove to the mouth. In the winter, there is an average of 850 individuals consisting mainly of Mallard (*Anas platyrhynchos*), American Black Duck (*A. rubripes*), Common and Red-breasted Mergansers (*Mergus merganser, M. serrator*), Canada Goose (*Branta canadensis*), and Mute Swan (*Cygnus olor*).

The river is also an important migration corridor for waterfowl in the spring and fall. During the spring migration period, large concentrations of waterfowl can be found in freshwater tidal marshes such as those at Whalebone and Pratt coves. Also, the natural impoundments on the river floodplain created by the spring freshet provide habitat for migratory waterfowl. The freshwater runoff from spring snowmelt inundates many low-lying marsh and floodplain areas, particularly Cromwell Meadows and Pecausset Meadows, creating attractive resting and feeding habitat.

During the fall, waterfowl originating from Canada, upstate New York, and New England start arriving in September and reach peak numbers in December and January. Some species such as Blue-winged Teal (*A. discors*) and American Green-winged Teal (*A. crecca*) are common only during the fall migration period of August to October; they then continue migrating farther south. There are about 20 species of waterfowl that regularly use the river during the period from spring to fall.

Figure 1. American Black Duck (Fusco)

The Connecticut River is especially important for American Black Duck (Figure 1). During migration and wintering periods, the most important habitats for Black Ducks in Connecticut are the tidal wetlands of the Connecticut River and tidal wetlands, bays, and mudflats along the coast (Merola and Chasko, 1989). Black Ducks originating in Canada and northern New England rest and feed here during migration. In the winter, the river usually provides open-water habitat at a time when much of the inland freshwater areas are frozen over. The Connecticut River wetlands have been identified as regionally important Black Duck habitat under the North American Waterfowl Management Plan.

The principal waterfowl species that nest in the lower Connecticut River are Mallard, American Black Duck, Canada Goose, and Mute Swan. Gadwall (*A. strepera*) and Blue-winged Teal are occasional nesters. The brackish marshes of the lower reaches of the river are important to nesting Black Duck which, unlike the Mallard, has not fared well in the suburban landscape of Connecticut. The large undisturbed wetlands in the lower river provide excellent nesting habitat for Black Duck.

RAILS

Rails are a family of wetland-nesting birds that are rarely seen during the breeding season due to the dense cover of their habitat and their reclusive behavior. They can slip through the sedges and cat-tails without moving the plants – hence the phrase "thin as a rail." Three species of rails are regularly found as nesters and migrants in the Connecticut River marshes: Sora Rail (*Porzana carolina*), Virginia Rail (*Rallus limicola*), and Clapper Rail (*Rallus longirostris*). King Rail* (*Rallus elegans*) and Black Rail* (*Laterallus jamaicensis*) are also present but are extremely rare. Rails commonly build their nests on the ground from whatever grasses, sedges, or cat-tails are present at the site, building the level of the nest up to a height above the reach of the tides. The river's many marshes and coves are important stopover areas for migrating rails. In the fall, Sora Rails are especially common in freshwater tidal marshes, such as Whalebone Cove, that have abundant wild rice.

Since 1993, the CTDEP's Wildlife Division has employed a call-response survey technique to census the population of breeding rails and other secretive birds. Tape-recorded calls of the birds are played back at survey points within the river's marshes. Rails are territorial nesters that will respond to the tape-recorded call as if it were an intruder by calling back and coming in close to investigate and challenge the interloper. Based on survey results from 1993 to 1999, the Virginia Rail stands out as the most abundant and commonly occurring rail species.

SHOREBIRDS

PLOVERS AND TERNS: Piping Plover (*Charadrius melodus*) and Least Tern (*Sterna antillarum*, Figure 2), listed as threatened in Connecticut (Piping Plover is also listed as federally threatened), nest on Griswold Point, a sand spit at the mouth of the river. Every summer since 1984 the CTDEP Wildlife Division has monitored nests as part of their Piping Plover/Least Tern Project. Because Connecticut's coastline is so highly developed and heavily used, there are very few sandy sites where these species can successfully breed. The eggs and chicks of these ground-nesting species are susceptible to predation. Animals such as raccoon, fox, house cats, and gulls are known to prey on their eggs and young. The adult nesting birds are sensitive to human disturbance and will leave the nest if people get too close to it. The eggs or chicks may then be exposed to the hot sun without an adult to shade them. In order to protect nests from these impacts, CTDEP Wildlife Division, with assistance from The Nature Conservancy volunteers, fence off the nests. Predator exclosures are placed around individual Piping Plover nests, where the wire mesh is open enough to allow the tiny Piping Plover adults to walk into and out of the nest area. Least Tern nesting areas, however, must be roped off since these birds fly into and out of their nests. This technique is not as effective as the individual nest fencing done for Piping Plover, but it has been shown to decrease human disturbance. Since 1995, additional funding for these protective measures has been awarded through the U.S. Fish and Wildlife Service Partnerships for Wildlife Program and the Connecticut Wildlife Income Tax Check-off Fund.

From 1985 through 2000, between 15 and 40 Piping Plover pairs have nested each year in the state, with approximately two to three pairs found on Griswold Point. Nesting success varies slightly from year to year, but the productivity, measured as chicks fledged per nesting pair, is high enough to sustain a stable population over time. Least Terns, on the other hand, do not seem to be faring as well. Based on population modeling studies, it is estimated that an average of 0.5 fledglings per pair of

Opposite page: Figure 2. Least Tern. (Rozsa)

Above: Figure 3. The Willet inhabits larger tidal marshes, including Great Island. (Fusco)

nesting Least Terns is needed for a stable population. Between 1985 and 2000, however, least tern productivity has averaged only 0.31 chicks fledged per nest, with levels meeting the 0.5 productivity requirement during just four years out of 16. On a broader regional scale, the population of Least Terns appears to be stable if one considers that numbers are rising or staying the same in neighboring states of Massachusetts, Rhode Island, and New York.

WILLET: The Willet is a medium-sized sandpiper that breeds in only a handful of salt marshes in the state, including Great Island, Old Lyme (Figure 3). This species was more abundant in the 19th century, but hunting and egg-collecting for food probably contributed to its extirpation from Connecticut's marshes (Bevier, 1994). In 1976, after an absence of nearly 100 years, it started breeding again in the state (Craig, 1990). Willet will likely continue to be found only in the larger marsh complexes since it is area-dependent (Benoit, 1997), meaning it preferentially uses large areas of suitable habitat and usually will not be found in areas below a certain minimum size.

MIGRATORY SHOREBIRDS: The river's intertidal mud and sand flats, and the freshwater and brackish marshes, are especially attractive to migratory shorebirds. The area regularly supports nine common species, though a total of about 30 species may be found. The most abundant species are Black-bellied Plover (*Pluvialis squatarola*), Semipalmated Plover (*Charadrius semipalmatus*), Greater Yellowlegs (*Tringa melanoleuca*), Lesser Yellowlegs (*T. flavipes*), and Semipalmated Sandpiper (*Calidris pusilla*). These species are commonly observed resting and feeding along the shoreline and on the marshes and mudflats during the migration periods of late spring and late summer.

SONGBIRDS

Tidal wetlands and forested floodplains and uplands support a variety of birds, particularly passerines (perching birds), better known as songbirds. A few of these species are wetland specialists that nest only in marshes. The distribution of marsh breeding bird species can be linked to the change in vegetation from salt to freshwater marshes. In salt marshes, the frequently flooded low marsh is dominated by a single species of marsh grass called smooth cord-grass (*Spartina alterniflora*). Another type of cord-grass, *Spartina patens,* is one of only a few species of plants that cover the high marsh and form extensive meadows. Bird species that are habitat specific for *Spartina*-dominated meadow marshes are Seaside Sparrow* (*Ammodramus maritima*), and Saltmarsh Sharp-tailed Sparrow* (*A. caudacutus*), both listed as species of special concern in the state (Figure 4). These marsh sparrows are most abundant on Great Island at the mouth of the river and rapidly decrease in abundance with increasing distance upriver. Additionally, these species, like the Willet, are area-dependent, and thus are less abundant or absent entirely on smaller marshes. Since they require large areas of *Spartina* meadow, the recent expansion of the invasive common reed (*Phragmites australis*) may be robbing them of critical habitat (Benoit and Askins, 1999; see Environmental Management Issues chapter for further discussion of common reed). Marsh Wren (*Cistothorus palustris*) and Swamp Sparrow (*Melospiza georgiana*), on the other hand, are not area-dependent and are more common. They build nests in tall reedy vegetation and are most abundant in brackish marshes such as Goose Island and Lord Cove where narrow-leaved cat-tail (*Typha angustifolia*) and common reed are the dominant plants.

Figure 4. Seaside Sparrow is a Connecticut species of special concern. (Fusco)

Many songbirds in the lower river valley are "Neotropical migrants," a large and diverse group of species that breed in the North American temperate zone and migrate south of the continental United States to spend the winter. As a group they have been receiving a great deal of attention in recent years because populations of many species are experiencing long-term declines. Approximately 76 species of Neotropical migrants breed in the area of the lower Connecticut River (Bevier, 1994; Connecticut DEP1994). Nineteen of these species (25%) are currently undergoing significant declines in the Northeast (Smith et al., 1993). Large unbroken expanses of forest in the Connecticut River valley, such as Burnham Brook Preserve, Devil's Hopyard State Park, and Nehantic State Forest, provide important habitat for numerous species of Neotropical migrants, many of which are sensitive to habitat fragmentation. These sizeable land areas support local populations of species that prefer large areas of wooded hillside (Worm-eating Warbler, *Helmitheros vermivora*), mature forest (Black-throated Green Warbler, *Dendroica virens*), or floodplain forest (Cerulean Warbler, *D. cerulea*). Additionally, many commonly occurring forest, woodland or shrubland songbirds with declining populations such as Scarlet Tanager (*Piranga olivacea*), Wood thrush (*Hylocichla mustelina*), Rose-breasted Grosbeak (*Pheucticus ludovicianus*), Eastern Towhee (*Pipilo erythrophthalmus*), and Red-eyed Vireo (*Vireo olivaceaus*) nest in the river valley. The river and its surrounding floodplains and forests, therefore, provide important nesting habitat for many songbirds including some declining species.

SWALLOWS

Post-breeding flocks of swallows, particularly Tree Swallow (*Tachycineta bicolor*), congregate in massive numbers in a few marshes along the river (Figure 5). In August and September each year, the swallows roost together every night before they eventually migrate south for the winter. At dusk, the sky is blackened by tens of thousands of swooping birds. At some unknown signal, they begin to spiral down to the reeds below, keeping an orderly funnel formation as they settle down to roost together for the night. Each morning, most of the birds fly off for a day of eating insects before coming back in the evening to again roost together. After this scene is repeated for a month or more, the swallows begin their southward migration.

Figure 5. Massive flocks of Tree Swallows roost together in late summer, before their southern migration begins. (Fusco)

RAPTORS

OSPREY: The osprey (*Pandion haliaetus*) is a large bird of prey that feeds on fish. Osprey construct large stick nests in snags (dead trees) or on the ground. Returning to the same nest year after year, the nest grows in size and can measure several feet in height. Ground nesting on beaches like Griswold Point and marshes such as Great Island was common before populations of raccoons and other nest predators increased (Figure 6). Osprey are opportunistic and also use man-made structures such as telephone poles and even buoys for their nests. At the river's mouth, there are many artificial nesting platforms placed in or near wetlands by the CTDEP Wildlife Division and volunteers as part of a recovery effort. Recently, predator guards have been placed on the poles to prevent animals such as raccoons from climbing into the nests to steal osprey chicks or eggs.

In the late 1930's and early 1940's, approximately 200 pairs of osprey nested at the mouth of the Connecticut River. By the 1960's, these numbers had declined to only a few nesting pairs due to eggshell thinning caused by the pesticide DDT. Subsequently, the osprey was listed as a species of special concern in the state. With the ban on DDT, and the placement of nesting platforms, the population in 1998 had rebounded to 20 pairs on Great Island and 44 pairs overall for the lower Connecticut River. For the state as a whole, numbers of nesting osprey have increased from a low of nine active nests in 1974 to a high of 162 in 1999. As a result of this remarkable, albeit only partial, recovery, the osprey was


removed from Connecticut's list of endangered, threatened, and special concern species in 1998.

BALD EAGLE: An important feeding and roosting area, the lower Connecticut River has one of the highest winter concentration sites for Bald Eagles (*Haliaeetus leucocephalus*) on the East Coast. This has led to a small boom in ecotourism that includes winter eagle tours on the river and the new Essex Eagle Festival. When waters farther north ice over, eagles travel south to the lower Connecticut River where the warmer waters and tidal action prevent the river from freezing. The DEP Wildlife Division and volunteers survey the entire river each year as part of the statewide wintering Bald Eagle population census. In 2000, 72 wintering Bald Eagles were counted statewide with 23 found on the Connecticut River.

LONG-LEGGED WADERS

Marsh creeks, pools, and shallow water intertidal areas around the river's wetlands provide foraging habitat for long-legged wading birds that eat small crustaceans and fish. Wading birds such as Snowy Egret* (*Egretta thula*), Great Egret* (*Casmerodius albus*) and Black-crowned Night-heron (*Nycticorax nycticorax*) are wetland generalists that use marshes mainly for foraging and nest primarily on offshore islands in Long Island Sound (Figure 7). Two species that do nest in the marshes are Least Bittern* (*Ixobrychus exilis*) and American Bittern* (*Botaurus lentiginosus*, Figure 8). Bitterns, like rails, are quite secretive, but occasionally may be seen foraging along marsh edges and mudflats.

Populations of many long-legged waders, especially Great and Snowy Egrets, were decimated during the 1800's when they were killed for their feathers. The millinery (hat-making) trade was in full swing and demand for the beautiful plumes of the wading birds was high. The Migratory Bird Treaty Act of 1918, however, gave protection to many birds, including waders. The Act prohibits the killing of any migratory bird or the taking of nests or eggs.

Left: Figure 6. This 1941 photograph shows what used to be a common sight – ground nesting Osprey. (Deane)

Center: Figure 7. Great Egret fishing in a tidal creek. (Fusco)

Right: Figure 8. Least Bitterns are secretive, little-seen birds that nest in tidal marshes. (Fusco)

**Listed on the State of Connecticut list of endangered, threatened, and special concern species. See Trust Species chapter for a complete list.*

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FISHERIES OF THE CONNECTICUT RIVER ESTUARY AND TIDAL WETLANDS

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THANKS TO THE PRESENCE of freshwater, estuarine, and marine habitats of the tidal river and the shoals at its mouth, the lower Connecticut River has 78 species of fish, the highest fish diversity in the region. As noted in the introductory chapter, the Ramsar Convention originally grew out of a concern for migratory birds. The Connecticut River was the first wetland of international importance designated under Ramsar to recognize fish as an important element in wetlands.

Anadromous finfish are of particular interest from a national and international perspective. The lower Connecticut River is the gateway these fish use to access upstream spawning habitat each spring. In the fall, adults and juveniles return to the sea. Many, like shad and herring, migrate south along the eastern seaboard of the United States. Salmon migrate northward into Canadian and international waters. All along these routes the migratory species become food for offshore groundfish, seabirds (e.g., terns, gulls, gannets) and marine animals such as dolphins and porpoises. Thus the fish populations of the lower Connecticut River have ecological and economic impact far beyond southern Connecticut.

COMMERCIALLY AND RECREATIONALLY IMPORTANT FISHERIES

The lower Connecticut River supports significant commercial and recreational fisheries. The commercial fishery focuses on American shad (*Alosa sapidissima*, Figure 1), white catfish (*Amerius catus*), channel catfish (*Ictalurus punctatus*), white perch (*Morone americana*), and American eel (*Anguilla rostrata*). Annual commercial landings of these species generate over $130,000 annually. Bluefish (*Pomatomus saltarix*), winter flounder (*Pleuronectes americanus*), summer flounder

Figure 1. American shad is one of the most economically important fish in the lower Connecticut River. (Raver/USFWS)

(*Paralicthys dentatus*), striped bass (*Morone saxatilis*), hickory shad (*Alosa mediocris*), and blue crabs (*Callinectes sapidus*) dominate the recreational harvest in estuarine portions of the project area. Largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieui*), northern pike (*Esox lucius*), white catfish, channel catfish, white perch, and yellow perch (*Perca flavescens*) are most important in upstream, freshwater locations. Striped bass are targeted by recreational anglers throughout the entire lower river. In recent years the number of recreational fishing tournaments, most notably for largemouth and smallmouth bass and catfish, has dramatically increased. The recreational fishery of the lower Connecticut River is estimated to sustain a total economic value of over $2 million.

ANADROMOUS AND CATADROMOUS — THE MIGRATING SPECIES

The anadromous community is composed of fishes that spawn in freshwater and use marine areas to mature. Most importantly, the river has one of the largest and most stable populations of American shad in the U.S. It supports one of the oldest, most productive, and most renowned commercial and recreational fisheries in the region. Similarly, the population of blueback herring (*Alosa aestivalis*) is estimated to be the largest in the world. Other related anadromous fish include the alewife (*Alosa pseudoharengus*), hickory shad (*Alosa mediocris*), and gizzard shad (*Dorosoma cepedianum*); the last is in the process of naturally colonizing the river through range extension. While these herring-type fishes are more common in the mid-Atlantic riverine systems to the south, this river also represents the southern range limits of Atlantic salmon (*Salmo salar*, Figure 2) and rainbow smelt (*Osmerus mordax*). The river's unique geographic location, productivity, and habitat variety allow it to support a correspondingly unusual diversity of both southern and northern fishes.

Figure 2. The Connecticut River supports the southernmost population of Atlantic salmon. (Hollingsworth/USFWS)

Of particular note is the presence of both the shortnose sturgeon (*Acipenser brevirostrum*, see side bar) and the Atlantic sturgeon (*Acipenser oxyrhynchus*). These species are known to use the mainstem waters for overwintering and feeding and, perhaps, to support juvenile development for the shortnose. White perch and sea lamprey (*Petromyzon marinus*) are two other prominent anadromous fishes of the lower

SHORTNOSE STURGEON

Figure 3. Shortnose sturgeon is a federally listed endangered species. (DEP)

Shortnose sturgeon (*Acipenser brevirostrum*) are found along the Atlantic coast in estuaries and large rivers (Figure 3). In the Connecticut River, they are found only in the mainstem, and are divided into two populations: a partially landlocked one between the Holyoke Dam and the Turners Falls Dam in Massachusetts, and another in the lowest reaches of the river. The shortnose sturgeon is the only fish in the Connecticut River basin that is listed as an endangered species by the Federal government throughout its range. Its decline is attributed to overharvesting in the 1800's and early 1900's for meat, skins, swim bladders, and eggs (or roe).

The shortnose sturgeon is a long-lived, slow-growing fish reaching a maximum length of 2 to 3 feet and weight of about 14 pounds. Sturgeons are ancient species with fossils dating back 65 million years. They are very distinctive, looking prehistoric with unique body armor of diamond-shaped bony plates called scutes. These fish are classified anadromous, migrating from the ocean to freshwater specifically to reproduce, but those that are not landlocked by dams are likely to be amphidromous, moving between fresh and salt water. Shortnose spawn in the spring, broadcasting their eggs in areas with a rocky rubble substrate. Once hatched, the young fish drift downstream and may eventually swim to brackish water.

To assess the Connecticut population, biologists from the Department of Environmental Protection captured live sturgeon, installed radio transmitters, and tracked their movements. Two fascinating aspects of sturgeon migration were revealed by this study. During the spring freshet, most of the sturgeon migrate to the mouth of the river, presumably in search of food. Later in the season, as river flows diminish, sturgeon disperse back up through the river, but regularly utilize a series of sites known as concentration areas. The population size in the lower river is estimated at 800 individuals. However, biologists have as yet been unable to locate significant numbers of juvenile fish, and studies on the distribution and habitat requirements of young sturgeon continue.

Connecticut River. While both are found in great abundance, white perch supports significant commercial and recreational fisheries. Although striped bass are not known to spawn in the Connecticut River, there is a very large run of the fish ascending the river while feeding on other fishes, most notably blueback herring. This run of popular game fish has evolved into a nationally renowned sport fishery and multi-million dollar industry.

The American eel is a catadromous fish, one that spawns in saltwater and moves to freshwater for development. It spends the majority of its life in the river, is abundant in all life stages from elver to adult, and is a nocturnal scavenger. The American eel is also fished commercially.

The linear, interconnected estuarine and riverine system that the lower Connecticut River provides is important as a migratory corridor for many fish species. It is critical to those that migrate upstream into Massachusetts and northern New England through an extensive biological corridor that links marine and estuarine waters of the Atlantic Ocean with freshwaters of cool, inland streams.

FRESHWATER SPECIES

Freshwater fishes are inhabitants of tidal and non-tidal freshwater or low-salinity portions (brooks, streams, ponds, and lakes) of a watershed. In the winter, some of these species will descend into brackish waters, where available. Many of the species are small to medium-sized, somewhat solitary in nature, and are commonly found foraging along the bottom or among aquatic vegetation. Freshwater fish are rarely found in salinities above 8 to 10 parts-per-thousand (ppt). Spawning and early development are usually restricted to non-tidal waters, and generally take place in late spring to early summer.

Fishes in the project area are both abundant and diverse. With over 28 species known to occur in the project area, the lower Connecticut River supports the most diverse freshwater fishery in New England. Northern pike, largemouth (Figure 4) and smallmouth bass, yellow perch, and channel and white catfish are the bulk of the recreational fishery and, to a lesser extent, the commercial fishery. In addition, the Connecticut Department of Environmental Protection maintains and manages a northern pike spawning marsh, using the progeny produced at the marsh to augment northern pike stocks throughout the state. Important freshwater fish families in the Connecticut River include *Catostomidae* suckers,

Figure 4. Largemouth bass are one of the more important freshwater recreational fish on the river. (Raver/USFWS)

Centrarchidae sunfishes, *Cottidae* sculpins, *Cyprinidae* minnows and carps, *Cyprinodontidae* killifishes, *Esocidae* pikes, *Ictaluridae* catfishes, *Percidae* perches, *Petromyzontidae* lampreys, *Salmonidae* trouts, and *Umbridae* mudminnows.

MARINE AND ESTUARINE SPECIES

The marine fish community includes over 25 species that commonly use the estuary and an additional 25 species that occasionally use the area. Of these, winter flounder, summer flounder, striped bass (Figure 5), and bluefish are commercially and recreationally important. Most notably, the estuary provides significant spawning habitat for the winter flounder, a species whose coast-wide stocks are decreasing.

Figure 5. The estuary portion of the lower Connecticut River is used by a variety of marine fishes, including striped bass. (Raver/USFWS)

Estuaries are important nutrient traps, which makes them especially productive and important fish nursery habitats. Estuarine fishes are resident species of tidal waters where salinities range from tidal fresh to marine, or from 0.5 to 30 ppt salt. Most estuarine species begin spawning in late spring and continue throughout most of the summer. Within this diverse group of fish, a general onshore and offshore pattern of seasonal movements occurs, i.e., upstream and towards shore in spring and summer, and downstream to deeper waters in fall and winter. The extreme abundance of estuarine fish and invertebrates adds immensely to the productivity of the overall system by providing a forage base of substantial proportions for piscivorous (fish eating) fish and birds, including several rare and endangered species of birds. The highly abundant bay anchovy (*Anchoa mitchilli*), Atlantic silverside (*Menidia menidia*), killifish (*Fundulus* spp.), and American sand lance (*Ammodytes americanus*), as well as grass shrimp (*Palaemonetes pugio*) and bay shrimp (*Crangon septemspinosa*), form the foundation of this highly productive system. In addition, shellfish such as American oyster (*Crassostrea virginica*) and soft-shelled clam (*Mya arenaria*) are characteristic of the estuary.

INTRODUCED SPECIES

Human impacts on aquatic species and ecosystems have always been a force in the evolution of fish communities. From the simple blockage of a stream corridor preventing anadromous fish from reaching their spawning habitat, to the intentional introduction of non-native finfish species, human-induced impacts have been profound. There are 33 known exotic fish species in the Connecticut River basin, most of which were intentionally introduced or manipulated to provide various aesthetic or fishery benefits. Many of the introduced species that were manipulated in the 1800's are now dominant in the system, including many *Centrarchidae* sunfishes and bass, and the common carp (*Cyprinus carpio*). The true impacts on fish communities may never be fully understood because it is difficult to separate the effects of introductions from the effects of existing physical, biological, and chemical factors on community evolution.

TRENDS AND SUMMARY

Steady declines in Atlantic fish stocks have been caused by overharvesting, as well as by non-fishing human activities in the watersheds and coastal zone. Typically in the Northeast, urbanization of the landscape has extensively disturbed and degraded aquatic habitats. Urbanization, agricultural practices, flood control, groundwater manipulations, and land clearing have a profound impact on stream hydrology, morphology, water quality, and biodiversity. Damming rivers has prevented fish from reaching their former spawning grounds. Moderate fishing activity has reduced the overall spawning stock, and coastal pollution has reduced the habitat available to these stocks, further reducing their reproductive capacity.

One of the greatest long-term threats to the viability of the ecosystem is the continuous loss of freshwater, estuarine, and marine aquatic habitats. Conservation and management of the Nation's resources is necessary to prevent overutilization, facilitate long-term protection, and provide for the realization of sustainable resources. The Connecticut River estuary and tidal wetlands of the lower river represent the most productive and diverse estuarine system for fisheries in New England. As a reflection of that productivity, this area also supports the greatest fishing effort, recreationally and commercially, of any river system in New England. The river's location in a densely populated region of New England, halfway between New York City and Boston, provides easy access for millions of anglers. This location, coupled with the river's high environmental quality, presents tremendous fishing and economic opportunities.

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TRUST SPECIES OF THE LOWER CONNECTICUT RIVER

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THE CONNECTICUT RIVER WATERSHED as a whole is remarkable for the number of rare and endangered species in its boundaries, and the lower river in particular is home to a high concentration of rare, declining, and protected life forms. The list grows even longer when one includes the additional species that receive protection via management plans. Collectively, organisms in all of these categories are referred to as trust species. Table 1 includes scientific names of most organisms in this chapter.

The mouth of the river and its tidal marshes have long been known to support exceptional clusterings of state, regionally, nationally, and globally rare and/or endangered species. Of special prominence in the lower river are wintering bald eagles (Figure 1), nesting osprey (*Pandion haliaetus*), shortnose and Atlantic sturgeon, piping plover, northern diamondback terrapin (*Malaclemys t. terrapin*, Figure 2), rare plants such as golden club, the extremely range restricted puritan tiger beetle, colonial waterbirds, rails, and other species of regional management concern. Harbor seals (*Phoca vitulina*) too, have recently become more common. The area is also one of the most important shortnose sturgeon sites in

Figure 1. The lower Connecticut River has one of the highest winter concentrations of the federally threatened bald eagle on the East Coast. (Fusco)

Figure 2. The northern diamondback terrapin is occasionally found in the brackish water of the Connecticut River estuary. (Fusco)

the region, both for spawning and feeding, and is the site of Atlantic salmon (*Salmo salar*) releases and restoration efforts.

Species for which there are management plans include migratory finfish like Atlantic salmon, American shad (*Alosa sapisissima*), blueback herring (*Alosa aestivalis*), alewife (*Alosa pseudoherengus*), gizzard shad (*Dorosoma cepedianum*), American eel (*Anguilla rostrata*), American brook lamprey (*Lampetra appendix*), white perch (*Marone americana*), striped bass (*Morone saxatilis*), shortnose sturgeon, and colonial waterbirds such as herons and egrets (see Fisheries and Birds chapters for additional information). Waterfowl receive special attention in the North American Waterfowl Management Plan and for one of the species emphasized in that plan, the declining American black duck (*Anas rubripes*), the lower Connecticut River wetlands and waters serve as particularly important habitat.

Figure 3. Golden club, found in the river's freshwater tidal wetlands, is a species of special concern in Connecticut. (Metzler)

The list of "rare" species that are officially classified as endangered, threatened or of special concern under the Federal or Connecticut Endangered Species Acts is impressively large (Table 1). The list emphasizes species that are known to be associated with tidal aquatic or riverside habitats. Of the 20 rare plant species that occur in the lower Connecticut, eight are associated with brackish wetlands and seven with freshwater tidal wetlands. Three occur on levees, one on coastal beaches, and one on uplands. Eastern lilaeopsis forms a six-centimeter-tall carpet below smooth cord-grass (*Spartina alterniflora*) in the low marsh zone. This diminutive plant is the smallest member of the carrot family, and produces a small flower cluster (botanically an umbel) with four to nine white flowers. Saltmarsh bulrush occupies the narrow section of the river from Upper Island to Lord Cove with oligohaline waters (from 3 to 8 ppt salt content). Above this section, the river bulrush (*Scirpus fluviatilis*) is dominant and below this zone is found the alkali bulrush (*Scirpus robustus*). An unusual and colorful plant of the freshwater tidal wetlands is golden club, a relative of jack-in-the-pulpit (*Arisaema triphyllum*) that lacks that plant's "pulpit" — a covering around the flower stalk known botanically as a spathe. The small, bright yellow flowers cover the otherwise white stalk (Figure 3).

The rarest of the tidal plants is Parker's pipewort. This plant has a small rosette of spongy leaves at its base and leafless flowering stems. The largest populations of Parker's pipewort occur in Maine, especially in Merrymeeting Bay, but the

Connecticut River supports the second largest population on the eastern seaboard. The species has declined throughout its range and in Connecticut.

Two rare plants are no longer present on the lower Connecticut River. The first, large marsh pink (*Sabatia dodecandra*), was once found in brackish tidal wetlands at the mouth of the river. It is possible that historic mosquito ditching activities contributed to the local extirpation of this plant. Beach panic grass (*Panicum amarum*) is a rare plant of sandy beaches that was historically reported from Poverty Island. Poverty Island was the western segment of Griswold Point (the sand spit on the eastern side of the river's mouth) that became detached when a coastal storm created an inlet in that beach during the early 1800's. The island migrated to the northwest and became attached to Great Island. Beach panic grass has never been relocated on either Griswold Point or Great Island.

The puritan tiger beetle, considered "threatened" at the national level, earned its name from its supposed tiger-like hunting strategy of chasing prey and capturing it with long mandibles (Figure 4). Extremely range-restricted, these beetles are only found at several Connecticut River locations, Chesapeake Bay, and Kent County, Maryland. Tiger beetle habitat is a tenuous one, since these organisims prefer to live in shallow burrows on dry, sandy beach, areas where scour from flooding is sufficiently high to remove the vegetation, but not cause the loss of burrow habitat. The life cycle of the beetle is two years. Eggs hatch in August or early September and the larvae burrow into sand and feed upon insects that enter the burrows. Beetles emerge during the second summer as adults. The habitat of the beetle is flood-prone and may be inundated in any given month with prolonged flooding occurring during the spring freshets. The Connecticut River populations have declined for a variety of reasons including loss or alteration of habitat from development and shoreline stabilization projects, dam construction and trampling. The Federal recovery plan for tiger beetles recommends reintroduction to suitable sites within the species' historic range. In 1993, the Wildlife Division of the Connecticut Department of Environmental Protection initiated a reintroduction project using adult beetles. While that project was not successful, beetle larvae were again transplanted from Connecticut to Massachusetts in 2000, and biologists were cautiously optimistic since sampling demonstrated a high survival rate of larvae.

Figure 4. A denizen of only few sandy beaches in the eastern U.S., the puritan tiger beetle is a federally threatened species. (Fusco)

Two noteworthy species are the Kemp's Ridley turtle (*Lepidochelys kempii*) and West Indies manatee (*Trichechus manatus*). The Kemp's Ridley turtle, one of the most rare marine turtles, nests on a single beach in Mexico. Juveniles have been known to occur in southern New England waters and their distribution is largely known from abrupt water temperature decline events in the fall that can cause cold-stunning. Several turtles found in the Peconic Bay on eastern Long Island were radio-collared and tracked in 1997. One of the turtles entered the Sound and, for a brief period, was in the mouth of the lower Housatonic River. We suspect that this turtle may visit the lower Connecticut River.

The most unusual visitor to the Connecticut River was a West Indies manatee. In 1994, a manatee surprised scientists when it made an appearance in the Chesapeake Bay. Named Chessie after the bay, it traveled the next year to New York, swam through New York Harbor, entered Long Island Sound, and ventured as far east as Point Judith, Rhode Island. Biologists observed Chessie at the mouth of the Connecticut River feeding on smooth cord-grass.

Table 1. Federal and state listed endangered, threatened, and special concern species occurring in the lower Connecticut River.

COMMON NAME	SCIENTIFIC NAME	HABITAT	STATUS
	BIRDS		
American Bittern	*Botaurus lentiginosus*	A	E
Bald Eagle	*Haliaeetus leucocephalus*	T, A	E, FT
Black Rail	*Laterallus jamaicensis*	A	E
Common Moorhen	*Gallinula chloropus*	A	E
Common Tern	*Sterna hirundo*	T, A	SC
Glossy Ibis	*Plegadis falcinellus*	A	SC
King Rail	*Rallus elegans*	A	E
Least Bittern	*Ixobrychus exilis*	A	T
Least Tern	*Sterna antillarum*	T, A	T
Little Blue Heron	*Egretta caerulea*	A	SC
Long-eared Owl	*Asio otus*	T	E
Northern Harrier	*Circus cyaneus*	A	E
Pied-billed Grebe	*Podilymbus podiceps*	A	E
Piping Plover	*Charadrius melodus*	T	T, FT
Saltmarsh Sharp-tailed Sparrow	*Ammodramus caudacutus*	A	SC
Savannah Sparrow	*Passerculus sandwichensis*	T	SC
Seaside Sparrow	*Ammodramus maritimus*	A	SC
Sedge Wren	*Cistothorus platensis*	A	E
Short-eared Owl	*Asio flammeus*	T	T
Snowy Egret	*Egretta thula*	A	T
Willet	*Catoptrophorus semipalmatus*	A	SC
Yellow-breasted Chat	*Icteria virens*	T	E
Yellow-crowned Night-heron	*Nyctanassa violacea*	A	SC

COMMON NAME	SCIENTIFIC NAME
	FISH
American Brook Lamprey	*Lampetra appendix*
Atlantic Sturgeon	*Acipenser oxyrhynchus*
Shortnose Sturgeon	*Acipenser brevirostrum*
	INVERTEBRATES
Cobra Clubtail	*Gomphus vastus*
Eastern Pearl Shell	*Margaritifera margaritifera*
Eastern Pond Mussel	*Ligumia nasuta*
Goldenrod Stem Borer	*Papaipema duovata*
Midland Clubtail	*Gomphus fraternus*
Puritan Tiger Beetle	*Cicindela puritana*
Riverine Clubtail	*Stylurus amnicola*
Slenderwalker	*Pomatiopsis lapidaria*
Tidewater Mucket	*Leptodea ochracea*
Woodland Pondsnail	*Stagnicola catascopium*
	PLANTS
Bayonet Grass	*Scirpus maritimus*
Canada Sandspurry	*Spergularia canadensis*
Cursed Crowfoot	*Ranunculus scleratus*
Eastern Lilaeopsis	*Lilaeopsis chinensis*
Eastern Prickly Pear	*Opuntia humifusa*
Eaton's Beggartick	*Bidens eatonii*
Field Paspalum	*Paspalum laeve*
Golden Club	*Orontium aquaticum*
Hudson Arrowleaf	*Sagittaria subulata*
Marsh Pink	*Sabatia stellaris*
Mudwort	*Limosella subulata*
Parker's Pipewort	*Eriocaulon parkeri*
Pygmyweed	*Crassula aquatica*
Saltmarsh Bulrush	*Scirpus cylindricus*
Sandbar Willow	*Salix exigua*
Seabeach Sandwort	*Honkenya peploides*
Swamp Cottonwood	*Populus heterophylla*
Torrey Bulrush	*Scirpus torreyi*
Wild Senna	*Senna hepecarpa*
Winged Monkey-flower	*Mimulus alatus*

KEY

Habitat

A – aquatic

T – terrestrial

HABITAT	STATUS
A	E
A	T
A	E, FE
T, A	SC
A	SC
A	SC
T	SC
T, A	SC
T, A	E, FT
T, A	SC
A	SC
A	T
A	SC
A	SC
A	T
A	SC
A	SC
T	SC
A	SC
T	E
A	SC
A	SC
A	E
A	SC
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Federal Status

FE – Endangered Species- in danger of extinction throughout all or a significant portion of its range.

FT – Threatened Species - likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

State Status

E – Endangered Species - native species in danger of extirpation throughout all or a significant portion of its range in the state and to have no more than five occurrences in the state.

T – Threatened Species - native species likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range within the state and to have no more than nine occurrences in the state.

SC – Species of Special Concern - native plant species or any native non-harvested wildlife species with a naturally restricted range or habitat in the state, to be at a low population level, to be in such high demand by man that its unregulated taking would be detrimental to the conservation of its population, or has been extirpated from the state.

ENVIRONMENTAL MANAGEMENT ISSUES ON THE LOWER CONNECTICUT RIVER

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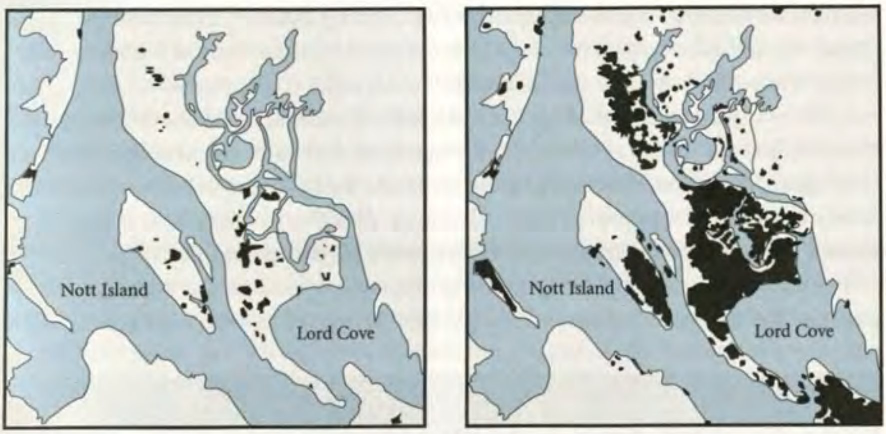
THE PURPOSE OF this chapter is to identify and discuss those environmental management issues that directly affect the conservation of living resources and their habitats in the lower Connecticut River. Such issues include control of invasive species, reintroduction of certain native species, ditching of marshes, dredging of navigation channels, stormwater runoff, boating, and ecotourism.

INVASIVE AND NUISANCE SPECIES

There are numerous non-native plants and animals found throughout the lower river, but only a small percentage are invasive and adversely impact river ecology. The notable invasive plants in the emergent wetlands of the Connecticut River are false



Opposite: Figure 1. Common reed is a tall, invasive grass that is spreading rapidly through Connecticut River marshes.

Above: Figure 2. Map showing a portion of the lower Connecticut River including Nott Island and Lord Cove in 1968 (left) and 1994 (right). The area in black is the extent of common reed, which increased dramatically during the 26-year period.

indigo (*Amorpha fruticosa*), Japanese stilt grass (*Microstegium vimineum*), and purple loosestrife (*Lythrum salicaria*). Most alarming is the rapid spread of the tall grass known as common reed or *Phragmites* (*Phragmites australis,* Figure 1). While common reed is native to North America, there appears to be a new and highly invasive form present throughout the Northeast. After examining historic aerial photographs, scientists at Connecticut College believe that the arrival of the invasive form of this species on the river occurred in the late 1950's. Prior to that time it was relatively uncommon in the region. Current rates of expansion are from 1% per year at Great Island to nearly 3% per year at Lord Cove (Figure 2). At these rates of spread, the native plant communities of the river may change to *Phragmites* monocultures in a mere 30 years.

Scientists are beginning to document the "leveling" effect that *Phragmites* has upon plant community structure and on the marsh surface. A typical brackish marsh will have a variable surface structure formed by pannes, ponds, short-meadow grassland, and swards of bulrushes of varying heights to monocultures of narrow-leaved cat-tail (*Typha angustifolia*). *Phragmites* converts this diverse structure into a uniform canopy. *Phragmites* monocultures greatly reduce plant biodiversity even when compared to typical stands of narrow-leaved cat-tail. In addition, under a canopy of *Phragmites*, the marsh surface becomes less uneven, and small depressions that fill with water are less common. This reduction in micro-topographic variation on the marsh surface may significantly lessen the habitat available to larval fish.

Dense *Phragmites* stands impose physical barriers to large birds such as waterfowl, egrets, and shorebirds that would otherwise use the surface of the marsh. While *Phragmites* may be beneficial to a few common marsh birds such as marsh wren

(*Cistothorus palustris*) and swamp sparrow (*Melospiza georgiana*), it can have a negative impact on specialized marsh breeders. Seaside sparrow (*Ammodramus maritima*), salt-marsh sharp-tailed sparrow (*A. caudacutus*), and willet (*Catoptrophorus semipalmatus*), all three listed as Species of Special Concern in Connecticut, are short-grass meadow specialists that do not nest in tall reedy vegetation such as *Phragmites*. In an attempt to safeguard the natural diversity of these wetlands, the Department of Environmental Protection (DEP) is employing and evaluating a variety of management measures to control the spread of *Phragmites* and restore native plant communities.

Eurasian water-milfoil (*Myriophyllum spicatum*) and pondweed (*Potamogeton crispus*) are two non-native plants associated with submerged aquatic vegetation (SAV).

WATER CHESTNUT

An emerging issue is the presence on the Connecticut River at Holyoke, Massachusetts of a highly invasive aquatic plant known as water chestnut (*Trapa natans*, Figure 3). Water chestnut spreads rapidly, can displace desirable SAV, is not readily consumed by wildlife, and can depress oxygen levels when the plants die back in late summer. Water chestnut produces a large spiny fruit, which can be painful if stepped upon. In 1998, the U.S. Fish & Wildlife Service initiated control measures for the Holyoke population. In 1999, State Department of Environmental Protection personnel discovered the first Connecticut population at Keeney Cove in Glastonbury. These plants were harvested immediately. A three-hectare (seven-acre) population was discovered on the Hockanum River in East Hartford too late in the year to harvest. The Hockanum River plants were harvested in the summer of 2000 using a mechanical harvester. Volunteers in canoes harvested chestnut in the shallow waters. The greatly reduced Keeney Cove population was hand harvested in 2000, as was a newly discovered population in the Podunk River. Since water chestnut can tolerate low salt concentrations, it has the potential to become an invasive plant in all the river's coves at least as far downstream as Essex. In the spring of 2001, a new population was confirmed in Eastford, which is located in northeastern Connecticut.

Figure 3. Water chestnut is the most recent invasive exotic plant threat to the lower Connecticut River ecosystem. (Hellquist)

Based upon a 1994 survey, neither plant can be characterized as invasive within the lower Connecticut River. The invasive aquatic plant Brazilian elodea *(Egeria densa)*, was recently discovered in a non-tidal pond near Chapman's Pond. No surveys have yet been conducted to determine its status in the Connecticut River.

The mute swan (*Cygnus olor*) is a European bird that has become thoroughly naturalized in Connecticut and other areas in the U.S. The number of mute swans in the Northeast continues to rise, with the greatest increase occurring in coastal tidal areas. Since 1972, wintering swans in the State of Connecticut have increased from 505 to at least 1,300. The number of breeding pairs has increased in direct proportion to the winter population. Mute swans are mostly non-migratory and large concentrations of individuals occur in both winter and summer in many of the major rivers near the coast. In the summer of 1993, over 800 birds were observed in the lower Connecticut River alone. Swans are aggressive and compete with native waterfowl for food and space, especially during the breeding season. They have been observed to consume tidal wetland vegetation including the rare golden club (*Orontium aquaticum*) and SAV. The swans' long necks allow them to browse beds of submerged aquatic plants to a depth beyond the reach of native dabbling ducks.

RESTORATION OF ATLANTIC SALMON AND OTHER FISH

Over 200 years ago, Atlantic salmon (*Salmo salar*) became extinct in the Connecticut River and other migratory fish populations were depleted (Figure 4). These declines and disappearance can be attributed to dam construction throughout the watershed and mainstem of the river, as well as overharvesting. The first dam built across the mainstem Connecticut River was constructed in 1798 near the present site of Turners Falls, Massachusetts. It, like other dams in the watershed, blocked access to spawning habitat in the headwaters and tributaries. Today there are over 1,000 dams in the watershed of the Connecticut River.

Figure 4. Atlantic salmon have been reintroduced to the Connecticut River after being extirpated by human activities, especially dam-building. (Hollingsworth, USFWS)

The Atlantic salmon is protected under the Anadromous Fish Conservation Act of 1965. Atlantic salmon and brook trout (*Salvelinus fontinalis*) are the only salmonids native to the Connecticut River; both brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynus mykiss*) have been introduced. Atlantic salmon restoration was first attempted in the 1800's, but ultimately failed due to lack of interstate cooperation. The current restoration of Atlantic salmon to the Connecticut River basin began in 1967. It is a major cooperative effort between the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, the U.S. Forest Service, the North Atlantic Salmon Conservation Organization, state fish and wildlife departments in the watershed, private organizations, and industry. The Connecticut River Atlantic Salmon Commission was established by Congress in 1983 to provide guidance and to ensure cooperation. Multi-state and federal cooperative management practices include raising salmon in hatcheries, capturing and spawning sea-run Atlantic salmon, stocking juveniles in tributaries, and providing access to habitat by building fish passage facilities. Over 1,000 miles of river and stream access have been restored through the use of fish ladders and lifts(Figure 5). These cooperative management efforts have resulted in the Connecticut River hosting the successful reintroduction of Atlantic salmon, a large and stable population of American shad, and the largest blueback herring population in the world. See the Fisheries chapter in this Bulletin for more on fish in the river.

MOSQUITO DITCHING ON MARSHES

Ditching marshes to reduce mosquito breeding habitat drains water from the marsh surface, lowers the water table position, and causes subsidence (lowering) of the marsh surface by as much as 30 centimeters (12 inches). In brackish marshes, ditching-caused lowering of the water table can adversely affect muskrat populations by stressing their food plant species and making their lodges accessible to predators. Muskrats may abandon ditched areas in search of more favorable wetlands. Critical habitats such as pannes and ponds disappear with ditching, contributing to decreased use by waterfowl, shorebirds, and wading birds. For example, near the mouth of the Black Hall River there are two unditched marshes, and bird use there is markedly different from the adjacent ditched and drained Great Island marsh. Along with pannes, stunted cord-grass (*Spartina alterniflora*) areas decrease and are replaced by short meadow grasses. The stunted cord-grass regions are critical habitat for the seaside sparrow and the saltmarsh sharp-tailed sparrow.

Ditching may also reduce soil salinities and thus create more habitat for colonization by common reed. The Department of Environmental Protection is experimenting with ditch plugging on Great and Upper Islands to determine if restoration of soil hydrology and salinity can reduce the spread of this highly invasive plant.

STORMWATER RUNOFF

For many years, stormwater was believed to have little or no impact upon wetlands and waters. It is now well documented that stormwater discharges do cause water quality degradation and loss of aquatic habitat. Large quantities of sediment transported in stormwater can actually bury habitats, including wetlands, intertidal flats, and submerged aquatic vegetation. Equally important in an estuary like the lower Connecticut is the dilution of salts caused by fresh stormwater discharges to wetlands. One consequence is that common reed expands in response to reduced soil salinity. Through a variety of "best management practices" and careful site planning, the impacts of stormwater on aquatic resources can be minimized or avoided.

DREDGING

There are approximately 20 shoal areas within the lower Connecticut River that require periodic dredging to provide safe passage for commercial waterborne traffic. Oil barges are currently the primary commercial vessels using the Connecticut River. The frequency of maintenance dredging is highly variable and is controlled, in large part, by the volume and velocity of river waters during the spring freshets. The authorized depths of the navigation channel are 4.5 meters (15 feet). Shoal sediments typically consist of clean sands that historically were disposed of in a variety of ways. Before the ecological significance of tidal wetlands was understood, marshes such as Nott Island and Calves Island were used as disposal sites for dredged sediments. Each shoal has a nearby mid-depth disposal location where it was determined that environmental impacts would be minor and acceptable. In the 1990's, DEP radio-tagged and tracked the movement of the endangered shortnosed sturgeon and determined that they concentrate at a few of these mid-depth sites. These specific locations are no longer used for disposal of sandy sediment.

WATER QUALITY

Over the last few decades there has been a tremendous improvement in Connecticut River water quality. Much

Figure 5. DEP Fisheries Biologist Stephen Gephard standing on the Mary Griswold Steube Fishway in Old Lyme, which allows migrating fish to navigate from the Connecticut River up a stream, past a dam. (Rozsa)

Figure 6. The presence of submerged aquatic vegetation (SAV) is an indicator of good water quality. (Rozsa)

of the improvement comes from establishing secondary sewage treatment plants for the major metropolitan areas, particularly Hartford in the late 1960s and Springfield in the late 1970s. Water quality also improved through new treatment technologies and through industrial facilities connecting to sewer systems. On the lower Connecticut River, new treatment plants were built in Chester in the early 1980s and Deep River in the late 1980s to reduce nonpoint source pollution. Water quality has also been improved through combined sewer overflow corrections (separating sewage and storm water) in Middletown, Portland, and Hartford. Long-term water quality monitoring has shown reductions in turbidity, total organic carbon, total phosphorus, dissolved iron, dissolved zinc, dissolved nickel, and fecal coliform. Oxygen levels have improved and nitrogen concentrations have increased slightly.

One of the best biological indicators of water quality is the presence or absence of submerged aquatic vegetation (SAV, Figure 6). As water quality improved on the river, especially decreases in nitrogen, phosphorus, and turbidity, SAV beds became reestablished. To some property owners, this restoration has been mistakenly viewed as a "choking" of river coves. SAV has high light requirements and can only grow in more shallow sections of coves, leaving the deeper water portions unobstructed. While direct, or "point," sources of nutrients like untreated sewage are declining, "non-point" sources, such as lawn fertilizers and residential septic systems, are on the rise. In eastern Long Island Sound, submerged eelgrass (*Zostera maritima*) beds are declining due to non-point source pollution, however no studies have been conducted on the Connecticut River to determine if there are SAV declines due to nonpoint source nutrient enrichment.

BOATING

Boats can impact aquatic resources in several ways. Boats require facilities to access the water, such as launching ramps, marinas, mooring fields, and individual docks. New construction activities must comply with federal and state permit requirements, which include avoidance of sensitive aquatic resources including tidal wetlands, intertidal flats, and submerged aquatic vegetation. There are several marinas on the lower Connecticut River, constructed before the passage of the Tidal Wetlands Act in 1969 (see Arboretum Bulletin No. 34), that were created from tidal wetlands by disposal of dredged sediments onto tidal wetlands.

Through the permitting process, DEP strives to eliminate or minimize impacts to coastal resources. Studies have shown that the shade cast by docks can reduce the productivity of submerged aquatic vegetation and tidal wetland plants, and that floats cause the loss of SAV. Wherever possible, new docks are placed where there are no tidal wetlands and SAV. When SAV beds cannot be avoided, the preferred dock orientation is north-south to minimize shading effects. In some circumstances the float and boats are placed beyond SAV beds to avoid or further minimize impacts to these productive habitats. Also, walkways to a dock across a tidal wetland must be properly sized and elevated to minimize shading impacts to emergent vegetation.

Once on the water, boats and jet skis can impact aquatic resources. Excessive boat speeds in narrow channels or adjacent to sensitive resources can cause habitat loss through wake-induced erosion. When motoring across submerged aquatic vegetation beds, especially at low tide, boat propellers can "mow" the plants, causing leaf loss. If the tide is too low and the propeller rotates through the mud, it can cause root damage and loss, leaving a long propeller scar. Studies have shown that it can take years for SAV to heal from propeller scars. Jet skis starting in an SAV bed may cause a circular depression, called a 'blowout', that becomes devoid of plants and roots.

ECOTOURISM

One of the fastest growing industries around the globe is ecotourism. Connecticut River ecotourism includes activities such as canoeing, kayaking, bird watching, and eagle cruises. The Connecticut River now supports one of the largest wintering populations of bald eagles on the Eastern Seaboard. Essex hosts a winter Eagle Festival, a testament to the on-going recovery of eagles since the ban on the pesticide DDT. Tourists on the Essex steam train and river cruises enjoy the scenic beauty of the river. A basic tenet to successful ecotourism is to assure that activities are done in a manner that preserves the ecological elements that are the basis of ecotourism. Canoes and kayaks provide access to shallow and remote waterways that are inaccessible to motorboats, which access to such may disturb wildlife such as nesting osprey. A number of canoe and kayak guides for the river and "A Code of Ethics for Wildlife Watching

Along the Connecticut Coast" have been supported by the Long Island Sound Fund to promote wise use of these species and places, and to increase public awareness about sensitive living resources.

SUGGESTED READING

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No.9. *Six Points of Especial Botanical Interest in Connecticut.* 32 pp. 1956. The areas described are the Barn Island Marshes, the Connecticut Arboretum, the North Haven Sand Plains, Catlin Wood, Cathedral Pines and the Bigelow Pond Hemlocks. **$1.00**

No.12. *Connecticut's Coastal Marshes: A Vanishing Resource.* 36 pp. 1961. Testimony of various authorities as to the value of our tidal marshes and a suggested action program. Second printing with supplement 1966. **$1.50**

No.17. *Preserving Our Freshwater Wetlands.* 52 pp. 1970. Reprints of a series of articles on why this is important and how it can be done. **$1.00**

No.18. *Seaweeds of the Connecticut Shore. A Wader's Guide.* 36 pp. 1972. Illustrated guide to 60 different algae with keys to their identification. New edition 1985. **$3.00**

No.19. *Inland Wetland Plants of Connecticut.* 24 pp. 1973. Some 40 species of plants found in marshes, swamps and bogs are illustrated. **$1.00**

No.20. *Tidal Marsh Invertebrates of Connecticut.* 36 pp. 1974. Descriptions and illustrations of over 40 species of mollusks, crustaceans, arachnids, and insects found on our tidal marshes. **$1.50**

No.21. *Energy Conservation on the Home Grounds- The Role of Naturalistic Landscaping.* 28 pp. 1975. **$1.00**

No.22. *Our Dynamic Tidal Marshes: Vegetation Changes as Revealed by Peat Analysis.* 12 pp. 1976. Description of a method for sampling peat and identifying plant remains in order to document vegetation change on tidal marshes. **$1.50**

No.23. *Plants and Animals of the Estuary.* 44 pp. 1978. Descriptions and illustrations of over 70 estuarine species. **$1.50**

No.24. *Garden Guide to Woody Plants- A Plant Handbook.* 100 pp. 1979. Lists and descriptions of over 500 different trees and shrubs useful for landscaping. **$2.50**

No.25. *Salt Marsh Plants of Connecticut.* 32 pp. 1980. Illustrated guide to 22 plants which grow in our tidal wetlands. **$1.50**

No.26. *Recycling Mycelium: A Fermentation Byproduct Becomes an Organic Resource.* 32 pp. 1981. Documents the role of industrial mycelial residues as soil amendments on ornamental plants, agricultural crops, and in natural vegetation. **$1.00**

No.27. *Birds of Connecticut Salt Marshes.* 48 pp. 1981. Illustrations and descriptions of 24 birds commonly seen on our tidal marshes. **$1.50**

No.28. *The Connecticut Arboretum: Its First Fifty Years 1931-1981.* 56 pp. 1982. Historical accounts of the formation and growth of the Arboretum. **$2.50**

No.29. *Mushrooms of New England.* 49 pp. 1984. Descriptions of 89 species of fungi, 62 illustrated. **$2.50**

No.30. *Native Shrubs for Landscaping.* 40 pp. 1987. Descriptions and lists of the best native shrubs for home, commercial and institutional landscaping. Color photographs. **$5.00**

No.31. *Birds of the Connecticut College Arboretum.* 50 pp. 1990. An annotated list with seasonal records, and an account of the bird research program. Illustrated. Replaces Bulletin No.10. **$5.50**

No.32. *The Connecticut College Arboretum—Its Sixth Decade and a Detailed History of the Land.* 96 pp., 47 photos. 1991. Historical accounts of the formation and growth of the Arboretum. Supplements Bulletin No. 28. **$5.00**

No. 33. *Archaeology in the Connecticut College Arboretum.* 56 pp. 1992. Detailed descriptions of prehistoric and historic archaeological sites in the Arboretum . Photographs and illustrations. **$5.00**

No. 34. *Tidal Marshes of Long Island Sound: Ecology, History and Restoration.* Describes the ecology and chronicles the history of Long Island Sound tidal marshes. Photographs and illustrations. **$2.50**

No. 35. *Native Woody Plant Collection Checklist.* 44 pp., 1 map. 1996. Listing in phylogenetic order of 288 taxa of trees, shrubs and woody vines cultivated in the Arboretum's native plant collection. **$2.00**

No. 36. *Amphibians and Reptiles of the Connecticut College Arboretum.* 52 pp. 1998. Field guide, checklist and summary of research on these animals in the Arboretum. Illustrated with line drawings, tables and graphs. **$5.00**

No. 37. *Living Resources and Habitats of the Lower Connecticut River.* **$5.00**

OTHER PUBLICATIONS

Connecticut's Notable Trees by Glenn D. Dreyer. 93 pp. revised ed. 1998. Memoirs of the Connecticut Botanical Society No. 2, 1989. Records the locations and stories of the historic trees that have witnessed major events in Connecticut's past, and the largest trees of each species: Connecticut Champions, New England Champions, and National Champions. **$12.95**

(plus postage & handling - $2.00)

The Wild Gardener in the Wild Landscape by Warren G. Kenfield. (Memorial Edition) 232 pp. 1991. The results of decades of creative research involving the scientific control of unwanted plants, combined with an extensive knowledge of plant ecology and horticulture to create an original volume for the homeowner as well as the estate manager. **$25.95**

(plus postage & handling - $4.00)

Connecticut Lakes by Richard Canavan IV and Peter A. Siver. 299 pp. 1995. A study of the chemical and physical properties of 56 Connecticut lakes, presenting both current information and summaries of previous studies. **$ 9.95**

(plus $4.00 postage & handling)

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