

LONG TERM DECLINE OF *ZOSTERA MARINA* IN LONG ISLAND AND FISHERS ISLAND SOUNDS

INTRODUCTION

A long-term decline of *Zostera marina* has occurred throughout the western and central portions of Long Island Sound. Currently, Eelgrass is predominant in Fishers Island Sound and the nearshore zone from New London to East Lyme. Eelgrass is present in the mouth of the Connecticut River but the population size and distribution are not known. The only extant population located west of this river is found in the Hammonasset River in Clinton. Nitrogen enrichment has been shown to cause hypoxia in western and west central Long Island Sound. The most probable cause of Eelgrass declines is light attenuation caused by increased phytoplankton production from nitrogen enrichment. Based upon an analysis of the historic data, we suspect that water quality problems existed in western and central LIS as early as 1930-1940.

The following recounts the historical distribution of *Zostera marina* in Long Island and Fishers Island Sounds and summarizes the post-1931 decline recovery. Current distribution data are presented. Water quality data collected in the open water of LIS are presented for the growing season of 1989 and 1990 to illustrate the likelihood that nitrogen enrichment is the probable cause of the documented historical declines.

HISTORIC DISTRIBUTION OF *ZOSTERA MARINA* IN LIS

The historic distribution of Eelgrass in the Sounds is reconstructed from the following historic botanical and vegetation literature:

Berzelius Society (1878) - "Abundant along the coast."

Bishop (1885) - "Common on coast" (i.e., within 30 miles of Yale University)

Graves et al. (1910): "Common along the coast in bays, salt rivers and creeks, growing on muddy or sandy bottoms."

Nichols (1920): "The most distinctive plant of muddy bottoms along the seacoast is eelgrass... ..this also grows on sandy bottoms but it never attains there the luxuriance which it exhibits where growing on muddy bottoms...So prolifically does it thrive in the shallow waters of protected harbors and coves that at low tide large areas of muddy bottom here will be almost completely hidden by its clusters of long, slender - leaves." This publication has a photograph showing eelgrass growing on the shallow subtidal flats of the cove at the mouth of the Oyster River on the border of West Haven and Milford.

Modern surveys by plant taxonomists confirm that the early botanists accurately recorded plant distribution, taking special note of unusual distributions and notable absences. Thus, if Eelgrass was restricted a particular region or regions of the Sounds, this would be reflected in their annotations. There is no question that the vegetation ecologist G.E. Nichols provided accurate

descriptions of the plant associations that occurred in Connecticut and elsewhere. From these references, one can only conclude that Eelgrass was found along the entire coast of Connecticut.

The distribution of Eelgrass in the New York portion of these Sounds is poorly known except that there are several key references which establish the presence of this species in western LIS. These are as follows:

Transeau (1913) - "in tidal creeks, such as that on the east side of Center Island or the north side of Llyods Neck, the Eel Grass Formation is dominant"

Johnson and York (1915) - "its abundance, gives character to large areas of the harbor bottom (i.e., in the Inner Harbor of Cold Spring Brook)"

Although these data are restricted to the Cold Spring Harbor area and provide little information for the central or eastern portions of the south shore of LIS or the Westchester County area, the data do establish that this species did grow and prosper in western LIS where natural light attenuation was the greatest. The significance of this will be explained later.

Other important sources of information are the historic plant collections which are preserved in various herbaria. Herbaria collections provide the following collateral distribution data:

Bushy Point Beach, Groton (1970, NEBS) specimen collected in water 15' deep
Alewife Cove (1945, Connecticut College Herbarium)
Madison (1874, UConn and Yale Herbarium)
Guilford (), UConn Herbarium)
Stratford (1927-Frash Pond)
Fairfield (1915, UConn Herbarium)
Westport or Norwalk ()
Cold Spring Harbor (1890, Brooklyn Botanical Gardens)

These data support the pattern that emerges from the botanical literature. In general, the number of voucher specimens for individual species in an herbarium are inversely proportional to the abundance of the plant. Thus, for common species which are ubiquitous, few plant specimens are collected and preserved.

F. M. Uhler, a wildlife biologist, conducted a survey of several important waterfowl areas in Connecticut in 1932. The one notable report is the account presented to him regarding the historical distribution of eelgrass in the vicinity of Nells Island near the mouth of the Housatonic River. He states in his report that "according to reports, eelgrass has been common in the channels at the south end of Nells Island and at other points in the mouth of the Housatonic." However, his survey, which occurred after the eelgrass decline of 1931, found no eelgrass plants.

Conard (1935) described the vegetation of Long Island in a transect from the north shore to the south shore in the vicinity of Cold Spring Harbor. Conard noted the absence of Eelgrass at that time in the wake of the major Eelgrass decline that occurred in the early 1930's along the entire western shore of the North Atlantic Ocean. In the Long Island vicinity, Conard (1935) noted that

Eelgrass had disappeared by 1932. It is important to note that the cause of this decline is still unknown and that the decline was just that, a reduction in numbers which was significant but that it was not actually extirpated in all areas. It is reported that Eelgrass in mesohaline waters, were frequently unaffected by the decline. The recolonization of Eelgrass probably occurred from within rather than without the Sounds although no factual data on this point have been found yet.

Evidently the mecca for historic estuarine research in LIS was the Cold Spring Harbor Laboratory. Many of the oldest records for marine invertebrates are described from Cold Spring Harbor. Very little research was directed toward the study of Eelgrass prior to the decline in the 1930's. A remarkable piece of literature, not heretofore acknowledged in the Eelgrass literature, is the investigation by Johnson and York (1915) which describe the relationship of estuarine plants to tide levels. This was done for the emergent species associated with the following environments: beach, dune, tidal wetland, intertidal flats and subtidal areas. Species studies in the aquatic environment include Widgeon Grass, Eelgrass and algae. These studies also mapped the areal distribution of plants and determined the floristic composition. This study may represent the only such historic baseline against which to measure changes which have occurred due to water quality degradation.

An example of the detail provided by Johnson and York for Eelgrass in Cold Spring Harbor is as follows:

"The densest stands of *Zostera* seen in the harbor are that east of the channel (see map in Appendix A) to the Outer Harbor...On these areas there may be from 500 to 2,000 leaf-clusters of *Zostera* to each square yard of bottom."

As noted previously, Johnson and York report the average lower limit of Eelgrass as $-3.0'$ mean low water with extremes to $-4.5'$ mean low water. Although there are no extant populations of Eelgrass in the Inner Harbor today, measurements of certain water quality parameters could be used to determine to what extent environmental conditions have changed here.

POST 1931 RECOVERY:

According to Cottam (1931), by the summer of 1931, at most localities from North Carolina to New England, the leaves of eelgrass became somewhat darkened, broke from the roots, and washed ashore in great windrows. At this time, less than 1% of the normal populations existed in most areas. By 1934, Cottam noted that in those areas with reduced salinities, eelgrass was showing signs of return. This decline also affected species that depended upon eelgrass, in whole or part, such as brant, certain waterfowl and fishing/shellfishing industries.

Cottam (1933) makes no specific reference to Long Island Sound.

Lewis & Cottam (1936) subsequently note that "every year since the eelgrass ... was largely destroyed ... there has been vigorous new growth of the plant in summer ... Every year, in the interval between late August and the following spring, most of the new growth has succumbed to the disease, with the result that, considering the coast (i.e., the Atlantic Coast) as a whole, there has been no permanent improvement in the condition of eelgrass." They further note that "In most of the Chesapeake Bay section of Virginia and Maryland, the plant has returned to almost normal

condition ... In general, the best return of the plant has been restricted to areas of reduced salinity, such as the more inland coastal bays and estuaries and the mouths of larger rivers. Most of the coastal bays have shown little or no improvement." There is repeated reference in the literature to rapid recovery in brackish waters and slow recovery in polyhaline waters. Although specific studies have not been found for Long Island Sound, it is highly likely that similar patterns of recovery occurred in the Sound. Lewis & Cottam also note that the Biological Survey (predecessor to the United States Fish & Wildlife Service) had begun eelgrass planting projects in the previous fall with seeds and whole plants. Biological Survey reports may contain historical data for LIS which should be searched for.

As part of a survey of aquatic vegetation of lakes and ponds on Long Island, Muenscher (1939) examined several marine waters around the island including Mt. Sinai, Port Jefferson, Northport, Oyster and Hempstead Harbors on the north shore. This field survey conducted in 1938 revealed with respect to Eelgrass "only scattered areas, most of them small, in Great South Bay and Oyster Pond on Montauk Point ... Wind-rows of eelgrass leaves ... were seen along the shore of Shinnecock Bay and Great South Bay." Apparently, no eelgrass plants were observed in the north shore harbors surveyed.

Subsequently, Cottam (1945) wrote an account as follows of Dr. W. S. Bourn's (a biologist with the Fish & Wildlife Service) visit to Connecticut in the latter part of October 1944. Bourn "reported that the water was too rough and conditions otherwise were not favorable for him to get out on the Sound by boat. Bourn watched for drift, however, and found it only in the Barn Island area (i.e., Little Narragansett Bay), where he observed a "considerable windrow of healthy eelgrass plants that had been obviously dug up by feeding waterfowl." He added that "the individual plants appeared healthy and were approximately four feet in length."

Given Bourn's limited field survey in 1944, the general summary of east coast trends by Cottam (1945) as reported below may be more revealing of the general trends occurring in LIS:

"The situation has been most variable and sporadic since the initial destruction of eelgrass in 1931 to 1932. Little or no improvement could be detected for several years after 1931. Often some recovery was noted, only to be wiped out again ... Along most of the Atlantic Coast of the United States and Canada, the situation is now somewhat better than it has been since 1931. Local units may be called fully recovered; other areas still are almost completely without eelgrass. During the first half of the summer of 1944 a most gratifying recovery was noted in the majority of areas along the coast. In August, however, the disease reappeared in a number of areas, especially along the Massachusetts coast, so that the situation in part of this area was considerably less favorable than it had been during the preceding 2 or 3 years. The situation along the United States coast is perhaps least favorable in the more open bays and estuaries of New Jersey and Maryland, and most favorable in the sandy loam areas of reduced salinity of Chesapeake Bay, Long Island, and part of the Maine coast. Though the situation in any local area is highly variable and unpredictable, the trend is toward restoration of the plant in all favorable areas along the coast."

For the year 1946, Cottam and Addy (1947) reported that eelgrass continued "its growth and spread all along the (east) coast. For Connecticut, they report that "limited data available indicate but slight improvement along the coast."

Phil Barske (1993, personal communication) assisted Rhode Island and the Connecticut Board of Fisheries and Game in the survey and transplanting of eelgrass. Regrettably, Phil had retired by the time of this query and had pitched his historic files. The following information was supplied by him from his personal diary:

April 22, 1947 - Eelgrass was dug at Niantic River for transplanting.

April 23, 1947 - Niantic River eelgrass is transplanted to Great Harbor in Guilford.

April 24, 1947 - Eelgrass is dug in the morning and transplanted at Rocky Neck, East Lyme in the afternoon.

April 25, 1947 - Eelgrass dug in morning at Niantic River and planted at Longshore Beach in Westport in the afternoon; plants set in water that would be 3 to 4 feet deep at high tide.

April 29, 1947 - Inspected Longshore plants at low tide "only a few plants still in the sandy weed (?) area, the rest had been planted at too high a tide and is a bed of mussels and lettuce."

Stevens et al. (1950) give the following general account of recovery:

Cottam mentions that "progress was encouraging from Long Island Sound northward" (based upon period from 1934 to 1937?). In 1940, "localized portions of coastal New England the plant is ten to fifty percent as abundant as it was before 1931."

Commenting on earlier observations that the condition of Eelgrass improved first in those areas of reduced salinity, Cottam said, "though improvement was first noticed in areas of reduced salinity, the condition is highly variable, in some areas of almost unmodified sea water, eelgrass has made an almost complete recovery, and in some areas of reduced salinity the situation is still most discouraging."

Based upon a USFWS survey in 1949 Stevens et al. (1950) noted that Eelgrass "shows a continued improvement in general recovery of former abundance in some areas. Certain locations in Chesapeake Bay, Long Island Sound and Buzzards Bay have shown vigorous return."

Stevens et al. (1950) provide the following summary: "At present we can only say with certainty that the destruction of eelgrass was wholesale in 1931-1932, that the plant has been recovering slowly, that some localities have made almost complete recovery while others have failed entirely. Considering the entire range of *Zostera* on the Atlantic coast of the United States of North America, there is more eelgrass at present than at any time since the great die-off."

Cottam (1954) presents the following account for the condition of Eelgrass in Long Island Sound:

"Though eelgrass is perhaps less abundant in this state than along most of the New England coast, the plant has shown encouraging improvement. In a few coves and bays, notably

Stonington Harbour, Mystic, Poquonock and Niantic Rivers, it is now regarded as abundant. Yet, in some adjacent areas beds are scarce or even nonexistent. Eelgrass is said to be practically absent near New Haven, Milford Harbour, Southport and Rowayton. Reestablishment on Long Island's north shore is noticeably poorer than that on adjoining coastal areas."

If we use a literal interpretation of the information listed above, it establishes significant recovery in eastern LIS and that plants were present in western LIS.

Several general observations made by Cottam at this time may have bearing on the recovery of Eelgrass in LIS. Most particularly "Evidence seems to indicate that shifting bottom soil, turbidity, erosion, pollution, encroachment by industry, unfavorably soft or sterile sandy bottoms, or other adverse physical or ecological conditions have prevented reestablishment of the plant in many areas where it once grew in profusion. Unsuccessful plantings occurred in the coastal waters of Massachusetts, Rhode Island, Connecticut, Long Island, New Jersey, Delaware, Maryland and Virginia." The reference to pollution above is noteworthy in that there is some evidence to suggest that higher water quality is required to restore eelgrass populations than to maintain established populations.

PRESENT DAY DISTRIBUTION:

No systematic surveys such as the aerial surveys which have been conducted in Chesapeake Bay exist for Long Island and Fishers Island Sounds. The most recent attempt (1991) to catalog and map present day distribution patterns was conducted by Juliana Barrett, ecologist for The Nature Conservancy. This information is principally based upon location information provided by a few individuals and should not be considered a complete survey. Locations from east to west reported in that survey include the following:

- Bay bounded by Stonington Point-Edwards Point-Sandy Point, Stonington
- Stonington Harbor, Stonington
- Lyddy Island to Lords Point, Stonington
- Dodges Island (east and west shores), Stonington
- Ram Island, Stonington
- Pine Island Bay, Groton
- White Point, Waterford
- Jordan Cove and Bay, Waterford
- Niantic River and Bay, Waterford and East Lyme

In addition to this survey, the following locational information is provided:

- Little Narragansett Bay - extensive eelgrass beds (Rozsa)
- Fishers Island Sound (Rozsa)
- Quiambog Cove - (Crawford, 1989)
- Mystic Harbor
 - small cove north of Masons Island Road, Stonington (Rozsa)
 - Willow Point vicinity Road, Groton (Rozsa)

Poquonock River, Groton (Rozsa)
Bushy Point Beach - Fishers Island Sound (Welsh, 1984)
Shennecosset Beach (Welsh, 1984)
Thames River (DEP- Marine Fisheries)
Thames River (Welsh, 1984)
 North of Quinnepeag Rocks
 Plant Street vicinity
 'Central Avenue' vicinity
Alewife Cove, Waterford – present but declining (Ralph Lewis, 1992, personal communication)
Black Hall River, Old Lyme DEP - Marine Fisheries, 1994)
South Cove, Old Saybrook (Abate, 1994)
Hammonasset River, Madison & Clinton (DEP-Marine Fisheries)
Hammonasset River, Madison & Clinton - extensive beds on the south or Hammonasset State Park side of the channel. A fringe of eelgrass occurs at the edge of the channel and intertidal flats on the north side of the channel (Rozsa)
Hotchkiss Grove, Branford - Bud Beckley, a wildlife biologist with the CT Board of Fisheries and Game reported that he had been planting eelgrass at this location for the past 30 years where it has been sprouting continuously. This bed(s?) were observed by Mike Ludwig of the National Marine Fisheries Service in 1982. The current status of this bed is not presently known.

Eelgrass attains its optimal abundance in the sheltered waters of Little Narragansett Bay and Fishers Island Sound. Consistent with historic records, Eelgrass today is restricted to sheltered bays and embayments.

The westernmost location known to the author for Eelgrass has been the Hammonasset River at least until the recent discovery of Bud Beckley's 1982 testimony as presented above. No locations are known to the west of the Hotchkiss Grove. The Marine Fisheries Surveys do not report Eelgrass in their inshore survey program from New Haven Harbor or the Housatonic River. No extant populations are known from the Long Island shoreline. John Black, a professor at Suffolk Community College (Marine Technology & Biology Departments) has studied various north shore coves and baymouth bars, such as Short and Long Beach, Mt. Sinai Harbor, and others since the late 1960's, and does not recall observing Eelgrass anywhere along the north shore of Long Island (personal communication, 1992).

A comparison of historic and present day Eelgrass locational information shows that Eelgrass is restricted to eastern 1/4 of LIS and is abundant in Fishers Island Sound and Little Narragansett Bay. This represents a significant decline in the Eelgrass distribution.

NITROGEN ENRICHMENT - THE PROBABLE CAUSE OF HISTORIC DECLINES

Based upon studies in other estuaries, the primary cause of declines in submerged aquatic vegetation is light attenuation caused by phytoplankton blooms resulting from nutrient enrichment.

The chief nutrient of concern in polyhaline waters, the predominant water type in Long Island Sound nearshore waters, is nitrogen. The Long Island Sound Study has identified one of the typical symptoms of nitrogen enrichment to be hypoxia, which occurs in large part due to excessive phytoplankton production. At times, hypoxic conditions exist throughout two-thirds of the Sound, occurring chiefly in central and especially western LIS, which coincidentally is the same geographic region where Eelgrass no longer occurs.

It is beyond the scope of this investigation to present a definitive water quality analysis to support this theory. The attached graphs plot dissolved nitrogen, total suspended solids and chlorophyll A data collected in the center of LIS along a west to east transect. Although this transect corresponds to the deep offshore areas, it probably represents a conservative picture of conditions that exist in nearshore areas.

To illustrate the relationship between water quality degradation and Eelgrass declines, the minimum SAV standards developed for Chesapeake Bay are imported here. These standards were developed specifically for polyhaline waters.

Dissolved Inorganic Nitrogen	<0.15 mg/L
Dissolved Inorganic Phosphorus	<0.02 mg/L
Chlorophyll A	<15 ug/L
Light Attenuation m^{-1}	<1.5 m
Secchi Disk	>0.8 m
Total Suspended Solids	<15 mg/L

In Chesapeake Bay, if several of these minimum requirements are exceeded, then submerged aquatic vegetation is usually not present. What emerges from the Long Island Sound water quality data are the following patterns:

TSS: The minimum standard is exceeded to the west of station I; this boundary closely corresponds with the western limits of Eelgrass on the north shore of LIS

Chlorophyll A: The minimum standard for Chlorophyll A is exceeded between stations E7 and C2 with values occasionally exceeding this standard to the immediate west and east of this range.

DIN: The minimum standard for nitrogen is exceeded principally west of station A2. At the reported concentrations, it is likely that nitrogen is directly toxic to eelgrass.

At this time, there is little or no light attenuation data or Secchi disk information [Note: DEP started collecting light attenuation data in 1992, this data has not yet been analyzed]. Light attenuation data collected at Holly Pond (Yarish & Baillie, 1989) at the 20% of incident light level necessary for the growth of Eelgrass occurs at approximately minus 1.3 feet. This is significantly less than the Chesapeake standard and is also significantly less than the historic depth of occurrence for Eelgrass for western LIS (i.e., Cold Spring Harbor). Mean surface TSS levels reported in Holly Pond range from 40 to 60 mg/L.

We expect that studies of the water quality requirements of Eelgrass in LIS will confirm that nitrogen enrichment is the primary cause of historic Eelgrass declines in central and western LIS. It is anticipated that non-point source nitrogen enrichment may be the cause of declines in certain eastern LIS embayments such as the Niantic River.

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