Quantitative and Qualitative Trends of Vegetative Tidal

Wetlands

In

New York's Marine District

With A

Focus On

Long Island Sound and Peconic Bay

By

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Abstract

Tidal Wetlands (TW) are the most productive, naturally occurring ecosystems along the northeast Atlantic coast, producing up to 4 tons of organic material per acre per year (O'Conner and Terry, 1972). Approximately 60% of the commercially harvested finfish and shellfish depend on the tidal wetlands productivity in addition to wildlife habitat benefits (Harmon, 1975). Historically, prior to the passing of New York State (NYS) legislation in 1973, tidal wetlands were considered a commodity, a health hazard, fast land and they were often dredged, filled and built upon.

The 1973 legislation and subsequent development restrictions, 6NYCRR, Part 661, have proved to be highly effective based on the 1989 trends analysis. Ironically however, historic and contemporary anthropogenic impacts have transcended time and combined with natural events and continue to negatively affect tidal wetlands causing their loss within NewYork's Marine District (Map1). Using GIS (Geographic Information Systems) technology tidal wetland complexes that exhibited qualitative vegetative tidal wetlands loss were subjected to quantitative assessment. In addition, some wetlands that exhibit loss, but were not included in GIS analysis, are also discussed and included in this report and should be quantitatively addressed in the future (Map2).

Introduction

Ever since the retreat of the last glacier some 10-15,000 years ago tidal wetlands have gained and lost ground. When immigration took hold, tidal wetlands succumbed to a force greater than any natural event, man and his incessant need to expand. Armed with the notion that he had dominion over all things natural (Grunwald, 2006), that wetlands were a vector for disease and fast land could be created by filling and dredging and become a commodity, Man began to destroy tidal wetlands. For example during the period 1954-1964 over 12,000 acres (30%) of tidal wetlands were destroyed due to filling and building activities (USFWS, 1965). During this time wetland laws were weak and not until the passing of the Tidal Wetlands Act in 1973 and the subsequent Land Use regulations, 6NYCRR Part 661, in 1977, did traditional filling and building activities cease. In 1974 a tidal wetlands (TW) inventory was conducted.

In 1989 a re-inventory and trends analysis was initiated. The re-inventory concentrated on the area of highest permit application activity Shinnecock and Moriches Bays marsh complexes. A conclusion of those reports stated, "that the regulations and the regulatory program were highly effective in stemming the tide of traditional filling and building

activities". The 1989 trends analysis also indicated that tidal wetlands were still experiencing losses especially on the marsh islands dominated by the grass *Spartina alterniflora* (Fallon and Mushacke, 1995; Mushacke, 1999). This was first quantified in Shinnecock Bay where vegetated marsh island losses totaled 15 acres. Further investigations revealed that this loss phenomenon was far more extensive, resulting in a marine district wide expedited trends analysis see (http://www.dec.ny.gov/lands/31989.html and www.

http://www.dec.ny.gov/lands/31879.html). These subsequent investigations compared the 1974 aerial infra-red inventory photos with contemporary true color and black and white aerial photos acquired from Suffolk County and New York State. Data from these analyses are included in this report to facilitate extent of tidal wetlands loss and research needs. Additionally included are qualitative comparisons of wetland complexes not yet quantified but suspected to exceed the 10% threshold set in the Strategy for Addressing Loss of Intertidal Marsh in the Marine District

(http://www.dec.ny.gov/lands/31879.html). The 10% threshold was developed as an indicator of losses greater than those experienced through a typical storm event or severe winter. The 10% indicator also reflects sustained losses over time (trends). Historically, a number of the complexes were 100% vegetated. All the wetland complexes examined quantitatively have experienced losses of greater than 20% except those at the mouth of the Nissequogue River which experienced a loss of 11.4% and while West Creek also exhibits losses in the 11% range, it's the invasion of the Intertidal Marsh (IM) into the High Marsh (HM) that makes this marsh complex significant and a subject of further discussion.

Methodology

Aerial infra-red imagery acquired in 1974 was compared qualitatively (visually) to various years of contemporary aerial photography for trends analysis. The 1974 imagery as well as subsequent aerial infrared imagery (1989, 1998, 1999, 2005 and 2006) was shot with the sole purpose of inventorying discrete tidal wetland zones and extent (see tidal wetland (TW) categories at http://www.dec.ny.gov/lands/5120.html). In order to be consistent over time certain conditions had to be met. These conditions were initially utilized in the acquisition of the 1974 IR imagery. The conditions required image acquisition at an altitude of 6,000 ft. with a resultant image scale of 1:12,000. This scale was judged optimum for providing a high resolution of detail for photo-interpretation and a sufficient level of detail for the production of the enlarged inventory maps (now in digital form and located at http://www.dec.ny.gov/lands/4940.html,

Offsite links, 1974 Tidal Wetland Inventory Maps). Additionally the images were to have photo end and side overlaps (67% and 27% respectively) to provide stereo viewing and mosaicing. The photos were to be taken during the height of the growing season (August through October) and within three hours of low tide for maximum vegetative and mudflat exposure. They were to be free of excessive haze, cloud cover and cloud

shadows. Infra-red (IR) imagery was the preferred choice because of its excellent haze penetration and its value for vegetative species discrimination

In order to compare the imagery and conduct trends analysis the IR images needed to be digitized, georeferenced and the tidal wetlands categories inventoried. The images were scanned at 600dpi using an Epson 1640 XL scanner and saved in *.tif format. They were then uploaded into ArcGIS 9.1 GIS software and geo-referenced. The geo-referencing protocol involved aligning the 1974 IR imagery to the 1974 tidal wetland inventory mylar maps, that were previously geo-referenced to the tidal wetland boundary line shapefiles which originated from the inventory mylars. This procedure was undertaken to insure accurate geo-referencing since the inventory maps were produced from the 1974 IRs and ground control points (landmarks) could be easily located on both the IR and the scanned mylar inventory map. After geo-referencing the 1974 IR, the 2005 imagery was georeferenced to the 1974IR imagery. All geo-referencing was done in Universal Transverse Mercator (UTM) North American Datum 1983 (NAD83). The coordinate system is the one used for the 1974 tidal wetlands inventory. Once geo-referencing was completed the images were photo-interpreted and tidal wetland class boundaries were drawn. The boundary designations are based on the 1974 mapping conventions, 6NYCRR Part 661, section 661.4 (hh) (1-6) tidal wetland boundary definitions and definitions found on the DEC website at http://www.dec.ny.gov/lands/5120.html.

Once the boundary polygons were drawn the software was queried to calculate the area of each polygon then the areas were grouped into their respective attributes, summarized and entered into Microsoft excel spread sheets for trends analysis. The focus of the spreadsheet was to show numerically vegetative tidal wetlands changes, if any, in intertidal and high marsh categories and to graph those trends. Tidal wetland classes other than IM and HM were not analyzed unless changes in these classes were observed in the field or through photo-interpretation.

Discussion and Results Long Island Sound

The primary focus of this report is the wetland complexes of Long Island Sound (LIS) and Peconic Bay. Grants were received from the Long Island Sound Study fund and Peconic Estuary Environmental Protection Fund for aerial infra-red photography so that trends analysis could be conducted using high resolution contemporary aerial infra-red imagery consistent with IR imagery acquired for the 1974 tidal wetland inventory. Additional qualitative and quantitative trends are included for Great South Bay and other areas throughout NY's Marine District; this was done to make the report more comprehensive regarding the extent of vegetative tidal wetland loss in Attachment 2 includes the expedited tidal wetlands losses from the DEC website http://www.dec.ny.gov/lands/31989.html. Detailed trends analysis from NY City will not be included since a report has already been written and trends established (Mushacke and Picard, 2002). When discussing the current total acreage of tidal wetlands NYC's wetlands acreage will be included however.

In 1974 overall inventoried vegetated tidal wetlands, for the marine district, totaled 28,751.51 acres with 17,499.25 acres IM and 9,311.4 acres HM. The remaining difference is Fresh Marsh (FM) (839.41acres) and Formerly Connected (FC) (1101.45 acres). The vegetated TW classes of (FM) and (FC) were not included in the trends unless changes were observed in the field or during photo-interpretation. If the FC was an integral part of the marsh system that significantly changed, it was reclassified to its current dominate vegetative type, and compared to its 1974 IR signature. If any of these conditions occurred they are noted. Based on contemporary trends, 16,487 acres of intertidal marsh and 9,264 acres of high marsh exist, totaling 25,751 acres an approximate loss of 3.95 %. These results are based on 10 sites that were fully quantified. There was a greater loss of IM 1,012 acres (5.8 %) than HM 47.4 acres (0.5 %).

In some complexes, for example, Crab Meadow, LIS, Hubbard/Mill and West Creeks, Peconic Bay, low marsh has invaded the high marsh and there is an increase of low vigor *S. alterniflora*, which, when contiguous with high vigor *S. alterniflora*, is classified as IM according to 1974 mapping conventions (Martin et al., 1975) This condition is an apparent reflection of higher tides and extended flooding duration. It appears to be a reflection of the first stages of the tidal wetlands loss phenomenon (Figure 1). Crab-Meadow is the best example of this occurrence. Another apparent sign is channel width increase and edge retreat. This latter condition could be considered advanced first stage or second stage depending on the extent of channel width and perimeter marsh condition. In Crab Meadow and West Creek, on the 1974 IR imagery, fragmentation of channel fringe IM can clearly be seen. On the 2005 IR, the channels are now Shoals and Mudflats (SM) (Figure 2).

The channels have widened an average of 90%. In Crab Meadow narrow areas of the main marsh, along natural channels and dredged mosquito ditches, are on the brink of breaking through (Figure 3). Throughout the main marsh 64 pannes have developed totaling 2 acres. While this area seems small 0.4% compared to the total area (489 acres), marsh pannes didn't exist in 1974. The Hubbard/Mill Creek, a similarly sized complex in Peconic Bay that did not contain marsh pannes in 1974 has maintained this condition in the 2005 imagery. Hubbard/Mill and West Creeks, who's HM has been invaded by low vigor S. alterniflora exhibits channel widening but the 1974 IR does not reflect the channel fragmentation phenomenon. The Hubbard/Mill Creek complex, a reference marsh complex (McDonald 2000), gained 81.64 acres (66.87%) of intertidal marsh, but lost 85.67 acres (30.17%) of HM (Figure 4). West Creek lost only 4.85 acres of IM (11.67%) the HM lost 4.41 acres (30.12%) (Figure 5). In the West Creek complex, significant vegetated marsh island loss was experienced (5.29 acres) but the edge loss that occurred along the main marsh is veiled by the invasion of low vigor S. alterniflora into the high marsh. In all these complexes there does not appear to be a proportional landward response by the high marsh at this time. The marsh/upland interface has apparently remained static even though the upland edge is gently sloped toward the wetland and in general is not hardened. Dead trees and a landward extension of the boundary line, through photo-interpretation, on the GIS and in the field are not apparent. Phragmites can be found along many of the boundary lines however, and except in the Fresh Creek marsh, Baiting Hollow, on LIS, and Accabonac, East Hampton it has not

made significant advancements into the HM or IM. Accabonac, however has not been quantified, however, and will need further study, see Qualitative Trends Analysis section. In addition to Crab Meadow four other marsh complexes within LIS embayments have been analyzed for trends; they are East Creek, Sands Point, West Pond, Glen Cove, Frost Creek, Lattingtown in Nassau County and Flax Pond, Old Field, Suffolk County. Because of their apparent similarities (small area, connection to LIS and general rural surroundings), IM dominant marsh class and the significant losses experienced by three of the four, they too have been chosen for further study marsh loss (Attachment 3). East Creek has not experienced loss and, will be used as a control in the additional study (Figure 6).

West Pond which is approximately 4.2 miles east of East Creek, has experienced a loss of 13.2 acres (60.55%) IM. From 1930 (earliest aerial imagery) to 1966 the marsh was 100% vegetated by *S. alterniflora*, but by 1974 the marsh exhibited fragmentation even though the trends indicate that there were still 21 acres of IM present. In this case the 1966 imagery revealed that the mouth of the Pond was void of IM and in 1974 IM was present (Figure 7). Image analysis from 1930 – to the present shows no additional anthropogenic impacts, except the addition of 3-5 estates and clearing for lawns. A circa 1900 USGS map however, shows a bridge rather than a solid fill roadway between Dosoris Pond and West Pond (Figure 8). On the 1926 and 1966 aerial photos ponding appears in West Pond, in the southeast portion, indicating that a culvert may have been installed after the construction of the solid fill roadway. In the 2005 imagery and field a culvert cannot be located (Figure 9) indicating a removal or failure of the culvert in the recent past. Absence of this structure may have been the key to IM loss due to lack of circulation due to loss of hydrologic connection.

Frost Creek (Figure 10) is approximately 2.6 miles east of West Pond in the village of Lattingtown, this is the third marsh complex in the aforementioned separate study. Frost Creek differs from West Pond and the other 2 complexes in that the marsh of interest is approximately 0.75 miles from its inlet and tidal waters travel through a golf course and are perhaps further influenced by an FC tidal wetland (Trubee Davison Preserve) approximately 0.15 miles from the mouth of the creek, before they reach the marsh proper. The tidal connection has been dredged in the past. The original path of the inlet has been altered by the construction of an historic boat mooring area which has now been abandoned (Figure 11). The vegetative marsh extent in 1974 covered approximately 71 acres; IM equaling 55.52 acres and the HM covering 15.45 acres. In 2005 the IM covered 29.28 acres and the HM 21.85 acres. Frost Creek vegetative wetlands experienced a loss of 29.28 acres (47.3%) of IM and a 6.4 acre (41.24 %) HM gain. Edge retreat of the IM appears to be the primary areas of the change, narrow channels and marsh fragments coalesced to form wider channels and fragmented IM tussocks have disappeared. Review of Nassau County's historic 1926 B&W aerial imagery shows a solid IM marsh although dark wet areas can be seen in the 1974 IR imagery that have begun to fragment By 2005 those areas were completely devoid of vegetation. The darkest areas on the 1926 aerials are the areas that are now completely devoid of vegetation while the lighter gray areas have fragmented and contain tussocks of IM (Figure 12).

Flax Pond is in Suffolk County, in the Village of Old Field, approximately 23 miles east of Frost Creek. It is the fourth of the marshes to be further studied for causes of

vegetative marsh loss. In 1974 IM comprised 60.42 acres and HM 20.32 acres. In 2006 IM acreage was 44.97 acres and HM 18.25 acres, resulting in a 15.4 acre (25%) loss of IM and 2.07 acres (10.2%) loss of HM (Figure 13). IM Loss is primarily from edge retreat and tussock erosion (in the western portion of the Pond). HM loss is primarily due to over-wash from a series of storms in 1992 and 1993 and the resultant restoration. A small amount of geomorphic loss approximately 0.75 acres occurred because of the expansion of a flood tide delta at the inlet (Figure 14). The delta grew approximately 100% from 1974 1.5 acres to 3 acres in 2006. It is theorized, based on preliminary studies of the tidal prism comparison from (Woodwell et al., 1973 and Brousseau, 2005) and a S. Baer's 2005 work correlating flood tide delta growth with TW loss, that the contemporary low tide is higher now then in the 1970s and that this condition is the primary cause of the 15.4 acre loss (Figures 15, 16, and 17). Further study is needed to confirm this hypothesis however. This theory and the recommendation for further study have been incorporated into the Flax Pond Unit Management Plan.

Discussion and Results Peconic Bay

Hubbard/Mill Creek is near the western intersection of the north and south forks along Flanders Bay. It's a Suffolk County park with portions located in Flanders and Southport and was selected as a reference wetland because of its outstanding landscapes setting and excellent adjacent communities (McDonald et al. 2000). IM in 1974 comprised 122.09 acres and HM 283.99 acres. In 2005 the IM comprised 203.72 acres and HM 198.32 acres. There was an 81.64 acre (66.87%) gain in IM at the expense of the HM which lost 85.67 acres (30.17%). The Hubbard/Mill creek complex experienced geo-physical losses along the barrier beaches in the western section of the complex (7.1 acres) at the mouths of Birch and Goose creeks as well as marsh island loss (1.7 acres) (Figure 18) in Hubbard Creek proper. Less than one percent of the dredged ditches have increased in width whereas near 100 % of the ditches in Crab Meadow have widened (Figure 2). Many of the ditches in the Hubbard /Mill creek complex have collapsed and/or grown over. Edge retreat occurred primarily along the main natural channel of Hubbard Creek (Figure 19).

West Creek is east of the Hubbard/Mill Creek complex on the north fork in the town of Southold. West Creek lost both IM and HM 4.65 and 4.41 acres respectively and similar to the Hubbard/Mill Creek complex the loss of HM was the result of IM encroachment. The gain of IM however was tempered by the 5.25 acre loss of IM islands. In 1974 IM comprised 41.63 acres while HM comprised 14.84 acres. In 2005 IM acreage comprised 36.77 acres (11.67% loss) and HM 10.37 acres (30.12%loss) (Figure 5). Corey Creek is also in the town of Southold on the north fork and is east of West Creek on the Hog Neck peninsula (Figure 20). Corey Creek IM experienced an IM loss of 26.93 acres (65.39%) and a 5.59 acre (47.41%) gain of HM from 1974 to 2005. Regarding the gain in high marsh, infra-red comparisons indicate that the barrier beach and a peninsular just north of the Corey Creek inlet contained dredged spoil that in 1974 had not revegetated. By 2005 the lack of spoiling and placement at the mean high water line

allowed the re-vegetation of HM to occur. IM loss is apparently due to subsidence and edge retreat from channel dredging compromising the marsh base infrastructure throughout Corey Creek, combined with a sediment budget disruption due to inlet and channel dredging

Cedar Beach is approximately 1.2 miles southeast of Corey Creek. Cedar Beach is a Suffolk County Park in the town of Southold that has experienced a 15.67 acre (55.4%) loss of IM and a 0.82 acre gain of HM from 1974 to 2005 (Figure 21). Loss is due to island marsh conversion from vegetated to non-vegetated conditions. Unlike Corey Creek however, it appears that the apparent key to the loss is due to a sediment budget disruption from dredged spoil placement on the beach raising the beach's elevation, widening it and preventing over-wash lobe sediments into the back dune area and onto the marshes.

Additionally, the dredging of the mouth has prevented depositional sands from building the marsh and helping the marsh maintain elevation against sea-level-rise. Dickerson's Creek is in the Town of Shelter Island on its southern shore in West Neck Harbor. Intertidal marshes experienced a 4.26 acre (49.76%) loss and the HM experienced a 0.34 acre (7.24%) loss (Figure 22). Primary loss was experienced by the marsh islands immediately inside the mouth of the embayment. Minor dredging was conducted in 1982 and spoil placement was upland. The County dredged to maintain flushing (Suffolk County Planning 1985). A sediment budget disruption may have occurred and is still occurring due to natural filling of the inlet and prevention of accreting sediments to marsh.

Qualitative Trends Analysis

The following trends were observed utilizing ArcGIS9.1 and its Swipe tool. This tool allows the viewer to overlay georeferenced images and once the tool is selected peel off the top image revealing the bottom image. Generally, to observe tidal wetlands trends, the 1974 IR was placed on top of the 2005 IR. Then the 1974 IR was the swiped and changes were observed. In cases where changes were observed a video *.avi file was produced for viewing by scientists, managers and the general public. This technique was used as a convenient diagnostic tool and a way to determine need for further investigation.

Caumsett State Park on Long Island Sound in Lloyd Harbor, Suffolk County is a pristine wetland complex with minimal perimeter development and no inlet stabilization or dredging. The marsh exhibits edge retreat, channel widening and fragmentation (Figure 23).

Accabonac Harbor on the Peconic Bay in East Hampton Suffolk County is a vast wetlands complex whose marsh is extensively ditched and inlet dredged. The marsh is experiencing loss through edge retreat, channel widening, fragmentation and, from the landward side, Phragmites infiltration. A vegetative shift from HM to IM is apparent in some areas along mosquito ditches which have widened further investigation and quantification is required (Figure 24).

James Creek, dredging of the natural channel and marsh occurred in the 60s which may have compromised the marsh infrastructure and accelerated subsidence. Personal communication with a property owner attributes some of the loss to goose herbivory (Figure 25).

Mashomack on Shelter Island is part of the Mashomack Preserve. Review of historic aerials (1930) reveals that the marsh complex may have been primarily HM and the main inlet was much narrower than it is today. The inlet has changed considerably since 1930 and 1974, currently the barrier beach has eclipsed the previous inlet location and a cut appears behind the barrier beach in the HM and IM. Internal IM collapse can be seen throughout the main marsh (Figure 26). The main channel has widened approximately 30%. Fragmented marsh in 1974 has disappeared and is now significantly smaller in size. Mosquito ditches appear to have remained stable and not widened. Since 1930 a vegetative shift may have occurred HM-IM due to the ephemeral nature of the inlet.

Mud/Broadwater Cove and Little Creek form a three prong creek system in East Cutchogue, town of Southold. A portion of the marsh complex is at the confluence of the three systems in Haywater Cove, they are in the form of IM marsh islands and the creeks have been dredged since 1966. Dredging has taken place directly adjacent to the IM marsh islands, in fact reviewing the 1930 aerial revealed that the islands had been partially dredged to gain access to all three embayments (Figure 27). The inlet is not stabilized and spoil placement has been to the west of the inlet on the south side of the beach. IM loss is occurring along the non-dredged portions of the marsh islands and is predominately occurring on the Haywater Cove marsh island. There is considerable residential development along these embayments including finger and floating docks. East Creek the western most creek in the complex is unbulkheaded while Broadwater cove is less than 10% bulkheaded and Mud Creek is less than 5% bulkheaded.

North Sea Harbor in the town of Southampton is experiencing channel and mosquito ditch widening and edge retreat. A number of internal terminal ponds connected to channels and ditches are expanding (Figure 28). Aerial imagery comparisons reveal that a vegetative shift has not taken place. From 1974 to 2005 marsh islands on the west side of North Sea Harbor inlet have sustained loss but predominately along the back side of the islands not along the dredged east side (Figure 29).

Oyster Ponds (Orient) in the town of Southold experienced marsh island loss, vegetative shift (HM to IM) channel widening and edge retreat and pond expansion. Despite the notion that this complex was suffering from Sudden Wetland dieback, examination of the 1989 aerial imagery revealed that some islands had begun to disappear, others had disappeared and pond expansion and channel widening had begun. Vegetated shifts had begun in the more restricted (FC) section of the complex to the north (Figure 30).

Potential Causes

There is no single, identifiable cause of the tidal wetlands loss phenomenon, natural and anthropogenic impacts could be acting singularly or synergistically. Historic as well as contemporary impacts can have negative effects on wetland benefits, functions and vegetative extent. Some of the causes discussed have not been identified/hypothesized in this region but have been implicated/suggested elsewhere, they are mentioned here as a resource.

Perhaps the single most suspected cause, regarding vegetative tidal wetlands loss is sea level rise (SLR) from global or local conditions. A number of conditions cause SLR, the melting of the ice cap, temperature (water expansion due to warmer water temperatures), crustal adjustments (the earth's crustal adjustments due to the removal of the ice following the last glaciation (Hartig et al., 2002). Another condition that may appear as a bona fide SLR phenomenon is pseudo sea level rise caused by the buildup of flood/ebb tide deltas and /or sills in dredged or un-dredged, mostly un-maintained inlets or restricted flows due to storm events and the subsequent delay of tidal ebb and /or elevated low tides due to the restriction of the inlet for example Flax Pond.

Sediment budget disruption causes a lack of sediment accretion on the marsh surface which the marsh uses to maintain its elevation against sea level rise.

The disruption can be caused by the growth of a barrier beach, inlet deltas, channel dredging and/or the installation of jetties or other structures that interfere with the natural movement of regenerative sediments into an embayment. Four marsh complexes, whose trends have been quantified East Creek, West Pond, Frost Creek and Flax Pond, will be undergoing further study to determine historic (²¹⁰Pb) and current (Sediment Elevation Tables SET and feldspar layer) sediment accretion rates.

Dredging channel adjacent to vegetated marshes can compromise the marsh infrastructure (generally sand base) causing accelerated subsidence. Subsidence leads to longer flooding duration, water-logging and death of *S. alterniflora*

Dredge spoil placement on barrier beach (beach nourishment) reduces or eliminates over time re-generative over-wash lobe sedimentation of back dune marshes.

Fusarium sp. a fungus thought to have been blown across the ocean from Africa possibly invades weakened S. alterniflora plants. It has not been found on S. alterniflora plants from Long Island marshes (Elmer, 2006, personnel communication). Fusarium sp. was found in plants from Louisiana in 2000-2001 (Schneider and Useman 2005).

Eutrophication affects sediment accretion by causing a positive feedback loop that leads to enhanced organic loading of the marsh. Bacterial oxidation of the organic matter may produce elevated levels of hydrogen sulfide in the marsh pore water. These high elevations may be toxic to *S. alterniflora*. Long term exposure to these elevated levels can lead to decreased biomass production and ultimately death of the plants. (Kolker 2005, Cochran, 2007 personal communication). Four marsh complexes, whose trends have been quantified East Creek, West Pond, Frost Creek and Flax Pond, will be undergoing further study to determine levels of sulfide in the sediment pore water. Algal matting or mulching this is the process of organic debris buildup on the vegetative

Algal matting or mulching this is the process of organic debris buildup on the vegetative portion of the marsh or on the naked peat. The buildup may crush young shoots or in the case of un-vegetated marsh sediment, prevent initial growth similar to garden mulch. The buildup also prevents oxygen exchange in the sediment at the sediment/water

interface and during the summer may cause excessive heat buildup prohibiting plant growth.

Ice scour a natural occurrence can scrape vegetation off the marsh at the root base. If ice builds up in biogenic holes the marsh may be hydrologicly torn from the marsh edge. The weight of ice on the marsh edge can also cause loss as it's heaved during wave batter.

Drought and has been suspected for some time especially in southern states like Georgia and Louisiana, to cause Sudden Wetland Dieback it has been explored in the New England states as well. The pathway is still unclear however. Sudden Wetland Dieback is not occurring in New York. To date all of the losses can be traced historically and have evolved over time.

Bio-eroders have been discovered in California salt marshes. Loss of the marsh is caused by the invasive Australasian isopod *Sphaeroma quoyanum*. The isopod burrows into the banks and mud of the intertidal marsh, weakens the mud and makes it susceptible to erosion by wave energy and creek /channel flow (Talley et al., 2001). The possibility of bio-genic holes from fiddler crabs causing similar issues hear has not been explored, however. Although burrows can be a conduit of loss, especially during winter freezing events, ice can form within burrows and hydraulically tear away marsh peat.

Conclusions and Recommendations

It appears that while the loss of the IM is very dramatic, the HM is also loosing ground. In some of the larger wetland tracts such as Crab Meadow and Hubbard/Mill Creek there were gains in the IM 63.54 and 81.64 acres respectively and significant losses in HM, 23.01 and 85.67 acres respectively. There is no apparent indication that landward migration has taken place. A small, less than 100 linear foot upland border at Hubbard/Mill creek, containing approximately 8 dead trees, may be an early indicator of SLR and landward migration. The predominately terrestrial under story did not seem to be affected, although the root systems may not be as deep as the trees or the understory vegetation may be somewhat salt tolerant. Further study of groundwater conditions in the area is needed.

In order to conduct an accurate trends analysis the 1974 inventory images should be reinterpreted and re-inventoried, previously they were inventoried for regulatory purposes, extensive qualitative and quantitative review of the imagery and the inventory maps revealed misidentifications, lumping of classes and because of time constraints small areas less than half an acre marshes were not mapped, additionally internal ponds connected to the main creeks were not mapped in many cases. On some maps with extensive shoals and mudflats, mixed with IM the entire area was mapped as IM, the western portion of Flax Pond map# 656-536 (Figure 31).

A complete contemporary inventory and trends analysis should be conducted to determine the full extent of loss.

Each marsh complex exhibiting loss or vegetative shift should be studied to determine potential causes and environmental triggers before restoration/rehabilitation efforts begin. Embayments of restricted or potential restricted flow should be identified and wetlands recovery/contingency plans adopted to prevent extensive loss.

Wetland complexes described in the qualitative trends analysis need to be quantitatively assessed.

While the IM loss appears more dramatic, because of physical changes from vegetated to non-vegetated wetlands, the HM is also under siege and may be a better indicator of loss. Because the two classes are vegetated, loss and fragmentation of the HM may not be as apparent. As sea level rises a false positive regarding IM totals may be seen, primary productivity may not drop as a result, in fact they may temporarily increase. This scenario may be an indicator of negative totals in the future, however.

Further historic profiling needs to be conducted to get a better understanding of events that may have triggered vegetated tidal wetlands loss.

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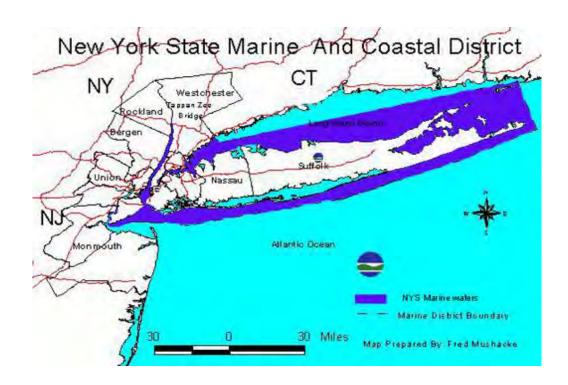
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ATTACHMENT 1

(Maps and Figures)

Map 1. New York's Marine District.



Map2. Study Area



Figure 1. An example of IM extent into the HM at Crab Meadow. Yellow is the 1974 IM extent, red is the 2005 IM extent.

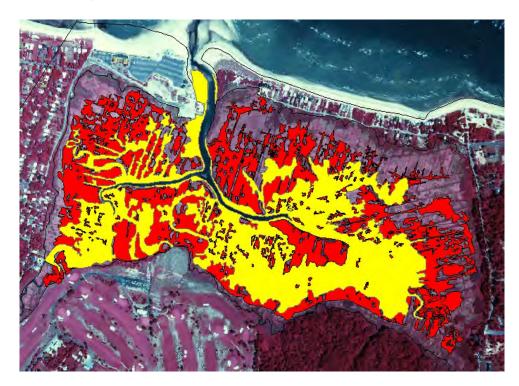


Figure 2. Fragmented IM along natural channels (1974) by 2005 the fragmented IM is gone and the channel has doubled in width.



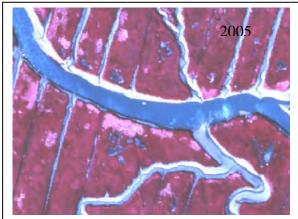


Figure 3. 1974 -2005 potential main marsh fragmentation and breakthrough.

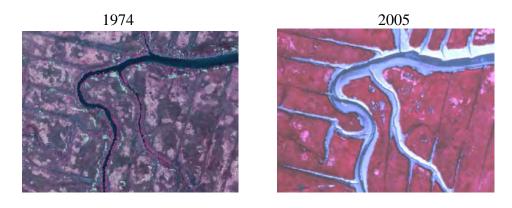


Figure 4, 1974 - 2005 Hubbard / Mill Creek, Southampton, Tidal Wetlands Trends Analysis

1974 TW Type HM IM	Count 123 44	1974 acres 283.9960 122.0870
2005 TWtype HM IM	Count 72 56	2005acres 198.3235 203.7191

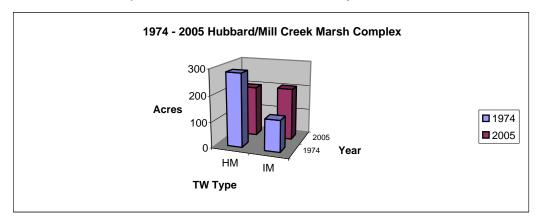
Tidal Wetlands Trends

1974 - 2005 Total acres gained/lost IM 81.64 66.87%

HM -85.67 -30.17%







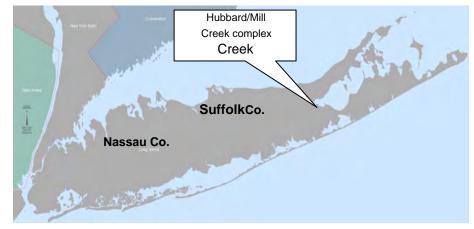


Figure 5. 1974 - 2005 West Creek, Southold, Tidal Wetlands Trends

TW Type	Count	1974 Acres
HM	39	14.8400
IM	41	41.6300

TWType	Count	2005 Acres
HM	12	10.3700
IM	33	36.7700

1974 IM acres 41.63 2005 IM acres 36.77

4.85 acres, 11.67% loss

1974 HM acres 14.84 2005 HM acres 10.37

4.41 acres, 30.12% loss



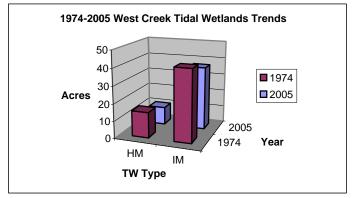






Figure 6. East Creek, Sands Point, Nassau Co., 2005 imagery with 1974 tidal wetland boundary line, this wetland complex has not experienced loss.



Figure 7. Mouth of West Pond 1966 absent of vegetation, 1974 vegetation present area circled.

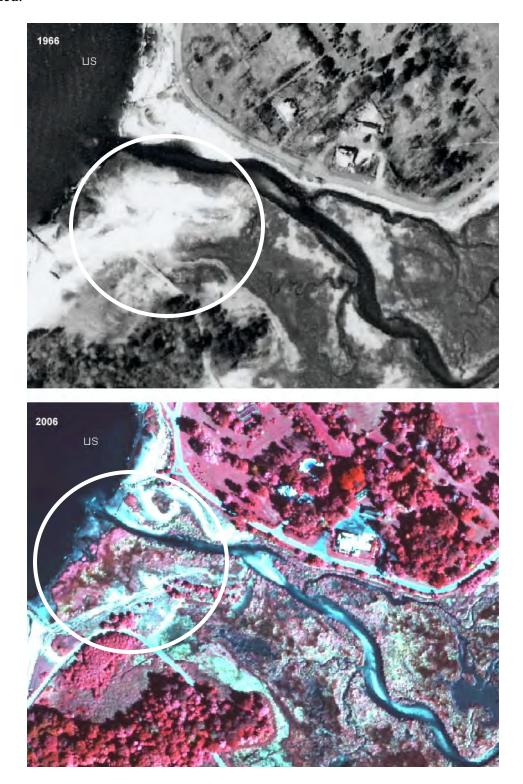


Figure 8 Circa 1900 USGS map of West Pond showing a bridge between Dosoris and West Pond allowing efficient flushing.

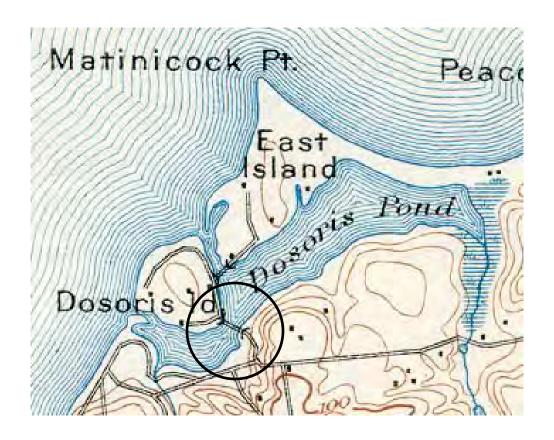


Figure 9. Culvert connection loss

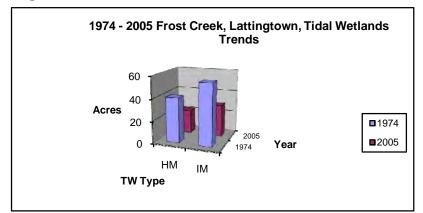




Figure 10. 1974 - 2005 Frost Creek, Lattingtown, Tidal Wetlands Trends

TW Type	Count	1974 Acres
HM	12	40.5200
IM	38	55.5200

TW Type	Count	2005 Acres
HM	7	21.8500
IM	59	29.2837



1974 IM acres 55.52 2005 IM acres 29.28

26.24 acres, 47.3% loss

1974 HM acres *40.52 2005 HM acres 21.85

18.67 acres, 46.1% loss

*FC and HM classes have been combined since vegetated species are the same and FC is a condition of connection to tidal waters, not a unique vegetative category.







Figure 11. Boat mooring area which was created circa 1940-50 that may have impacted the hydrologic connection.





Figure 12. Dark gray areas indicating lower IM in 1926, in 2005 these areas are completely devoid of IM. This condition may be an early indicator of potential vegetated TW loss areas for future complexes.

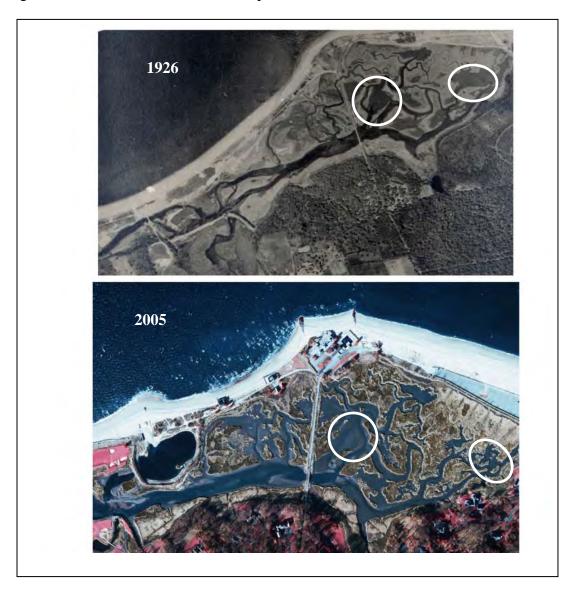
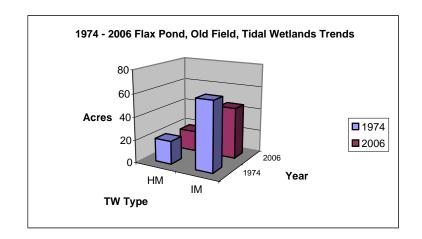


Figure 13. 1974 - 2006 Flax Pond, Old Field, Tidal Wetlands Trends

Count	1974 Acres
13	20.3181
69	60.4170
	13

TW_Type	Count	2006 Acres
HM	20	18.2518
IM	26	44.9708



1974 IM acres 60.4 2006 IM acres 45

15.4 acres, 25% loss

1974 HM acres 20.31 2006 HM acres 18.25

2.06 acres, 10.2% loss







Figure 14. Flood tide delta growth from 1974 - 2006, note circled areas, growth into existing 1974 IM extent.

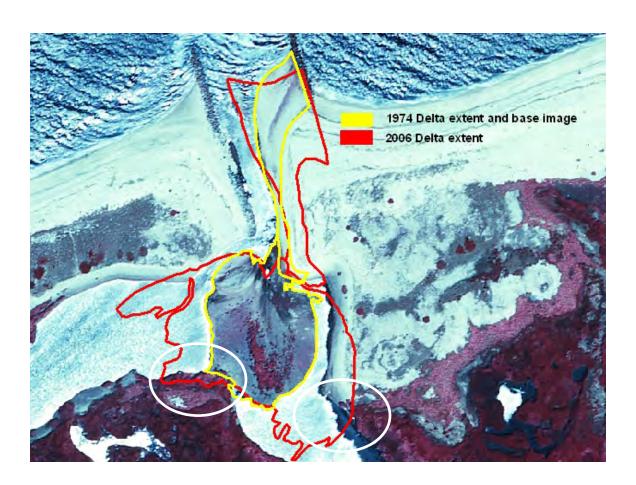


Figure 15. Delta growth at Flax Pond 1954 - 1966, potential cause of vegetated tidal wetlands loss



Figure 16. Delta growth vs. TW loss correlation.

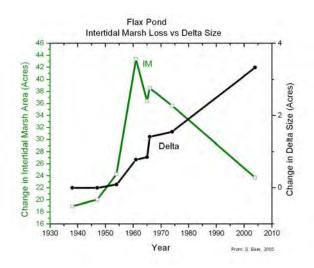


Figure 17. Comparison of 1973 Woodwell and Pecan tidal prism observations (black) and Lorne Brousseau's 2005 preliminary observations (red and blue). Note higher low tide elevations.

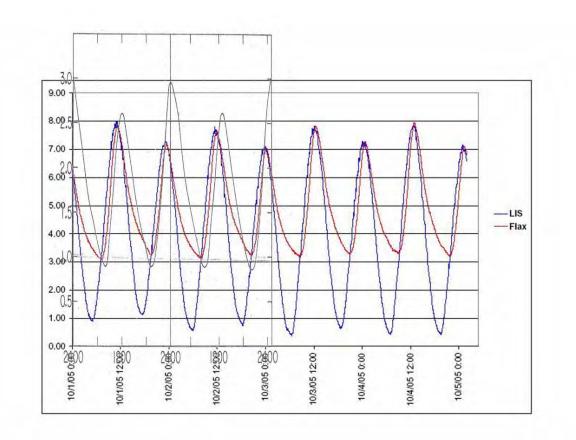


Figure 18. Geo-physical loss in the Hubbard/Mill Creek complex. Exposed red edge represents IM that existed in 1974, yellow represents 2005 IM seaward edge.

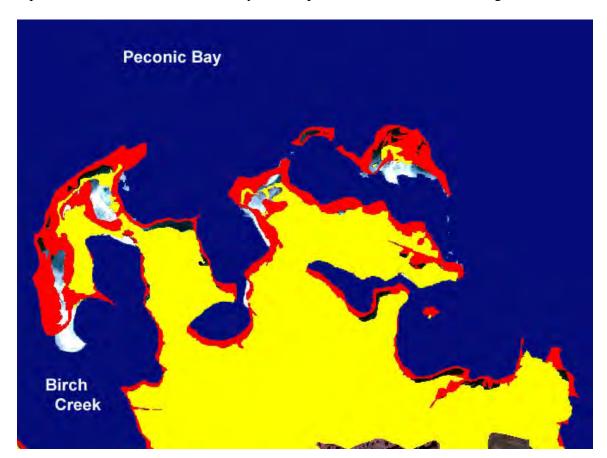


Figure 19. Island Loss in Hubbard Creek proper. 1974 vegetative extent in yellow, 2005 baseline IR. Note retreat of islands, complete loss of island in main channel circled and non-widening of ditches.

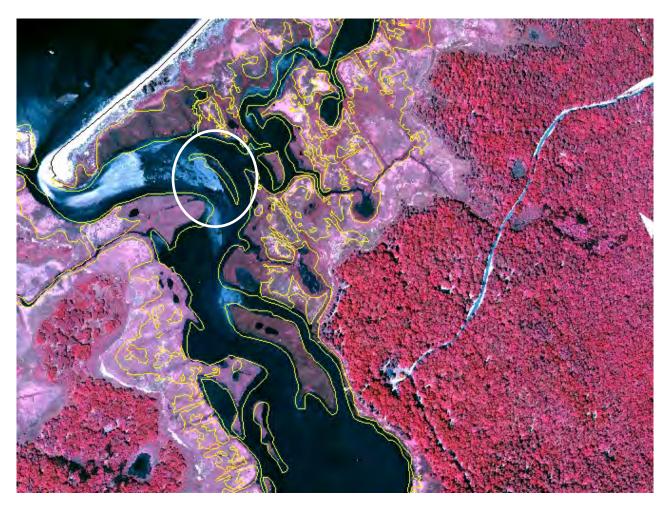


Figure 20. 1974 - 2005 Corey Creek, Southold, Tidal Wetland Trends

TWType	Count	1974 acres
HM IM	23 32	11.7960 41.1820
TW_Type	Count	2005 acres
HM IM	22 36	17.3800 14.2500
1074 IM coro	. 11 100	

1974 IM acres 41.182 2005 IM acres 14.25

26.93acres, 65.39% loss

1974 HM acres 11.79 2005 HM acres 17.38

5.59 acres 47.41% gain

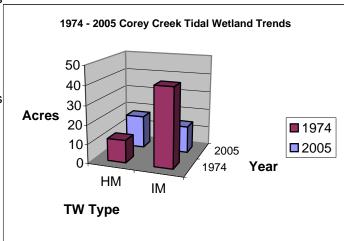








Figure 21. 1974 - 2005 Cedar Beach, Southold, Tidal Wetland Trends

TWType	Count	1974 acres
HM IM	2 11	4.7250 28.2890
TW type HM IM	Count 13 52	2005 acres 5.5404 12.6210

1974 IM acres 28.29 2005 IM acres 12.62

15.67 acres, 55.4% loss

1974 HM acres 4.72 2005 HM acres 5.54 0.82 acre gain

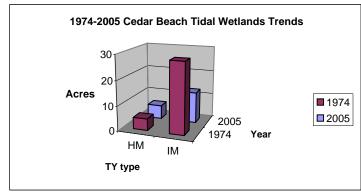








Figure 22. 1974 - 2005 Dickerson Creek, Shelter Island Tidal Wetland Trends

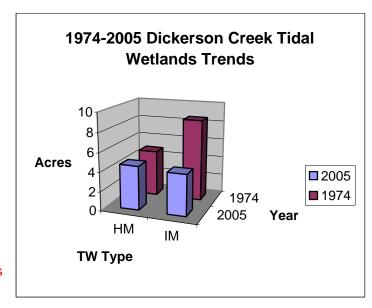
TW Type	Count	1974 Acres
HM	4	4.8330
IM	3	8.5570
TW Type	Count	2005 Acres
HM	8	4.5885
IM	14	4.3007

1974 IM acres 8.56 2005 IM acres 4.3

4.26 acres 49.76% loss

1974 HM acres 4.83 2005 HM acres 4.58

0.34 acre 7.24% loss



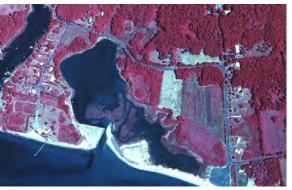






Figure 23. 1974 – 2005 Qualitative comparison of Caumsett Park. Note channel widening and fragmentation of internal marsh, circled in white.



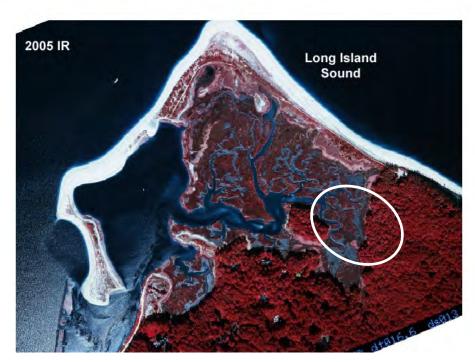


Figure 24. 1974 – 2005 comparrison of a portion of Accabonac Harbor, East Hampton, channel widening and fragmentation circled in white. Located at the Kaplan Meadows Sanctuary.





Figure 25. James Creek, Southold, site of loss circled in white.



Figure 26. Mashomack marsh, note changes in inlet configuration and resultant marsh loss circled.

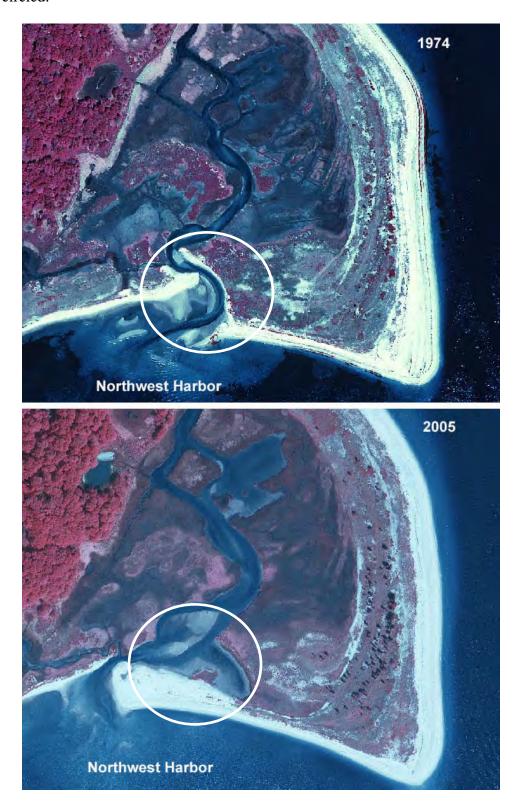


Figure 27. Mud/Broadwater Cove complex effects of direct (white) and indirect (yellow) dredging from 1930 – 2005, circled.



Figure 28. Channel and ditch widening on east side of North Sea Harbor

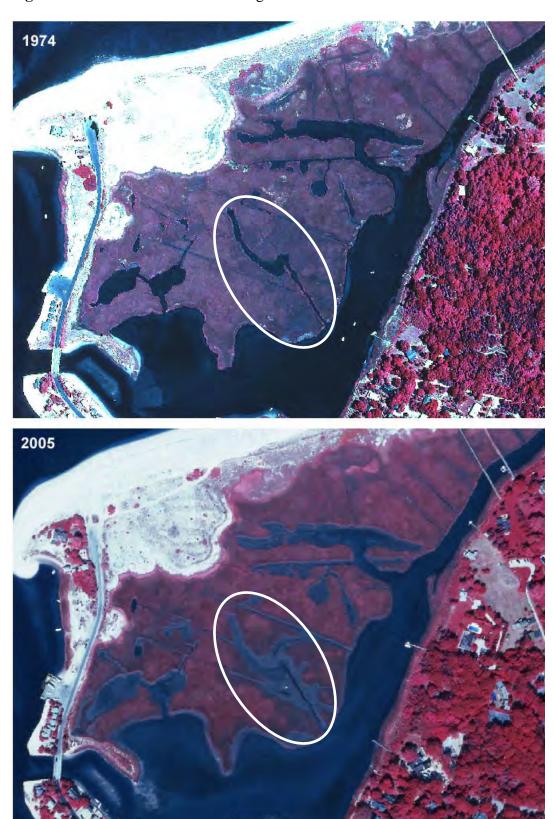


Figure 29. Vegetation loss on opposite side of dredging area in main channel of North Sea Harbor.

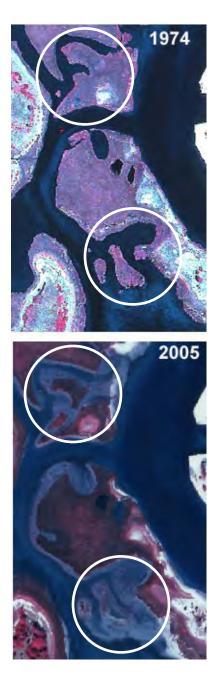


Figure 30. Orient, Oyster Ponds, island loss (white), vegetative shift, edge retreat and pond expansion (yellow).

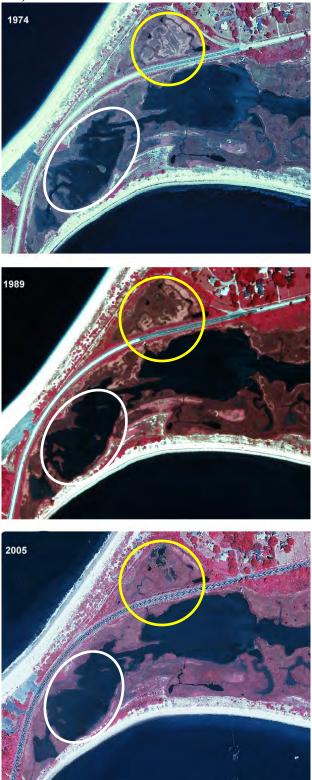
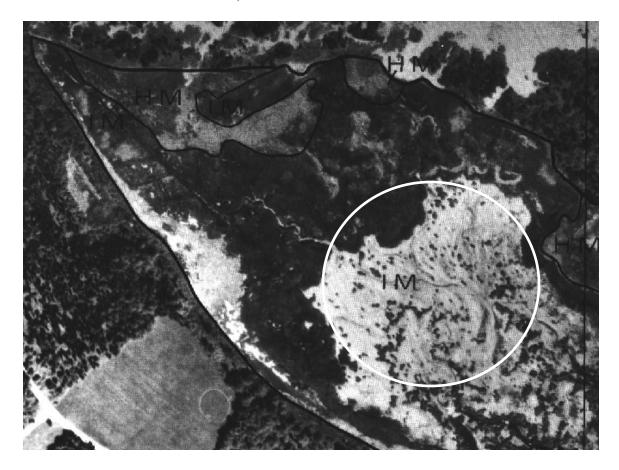


Figure 31. Flax Pond TW inventory map 656-536 (western portion) lumping extensive mudflats into intertidal marsh IM, circled.



ATTACHMENT 2 (expedited trends from; http://www.dec.ny.gov/lands/31989.html)

To fulfill a marsh loss strategy requirement, as described in <u>Tidal Wetlands Loss Strategies</u>, the Department conducted an expedited trends analysis of tidal wetlands in Nassau and Suffolk Counties. The areas of interest covered harbors, bays and rivers on the north and south shore and Peconic Bay. On the north shore 5 areas were explored: Manhasset Bay, Nassau County, Nissequogue River, Stony Brook Harbor, Flax Pond and Mount Sinai Harbor, the latter four in Suffolk County. On the south shore western bays in Nassau and Suffolk were also studied including: South Oyster Bay (Gilgo Islands and Goose Island), Middle Bay (West Islands) and islands in East Bay. In Peconic Bay, Corey and Cedar Beach Creeks were analyzed. Target sites within these areas of interest were chosen because they showed signs of loss during flyovers and field inspections.

The trends analysis included examination of aerial infra-red photographs from 1974 (photos of the original tidal wetlands inventory) and contemporary aerial photography (1994 New York State Digital Ortho Quads, 1999 Suffolk County Planning aerial photographs, 1998, 2001, 2002 true color aerial photographs). All photographs showed the tidal wetlands boundary clearly. As with the Jamaica Bay work, the photos were digitized and placed in a Geographical Information System (GIS). The tidal wetlands boundary (TWB) was then digitized, creating a second component of the GIS by which the area of the tidal wetlands could be assessed. The following tables show the trends of targeted wetlands on the North Shore, South Shore and Peconic Estuary.

Acreages of North Shore Targeted Tidal Wetlands in Nassau and Suffolk Counties

	Targeted Wetland	1974 acreage	1994 acreage	1999 acreage	Acres Lost	% Loss	Acres Lost/Year
Manhasset Bay	Kings Point	2.3	0.48	*	1.82	79	0.091
	Plum Point	7.36	4.23	*	3.13	42.5	0.15
	Manor Haven	8.91	3.42	*	5.49	61	0.25
	South Manhasset Bay	5.34	1.28	*	4.06	76	0.2
Nissequogue River	Center Island and East Shore	61.14	*	54.18	6.96	11.4	0.278
Stony Brook Harbor	Youngs Island	70.58	*	29.96	40.62	57.5	1.62
Flax Pond	Entire Pond	73	*	58	15	20.5	0.75
Mount Sinai Harbor	Center Marsh Islands	95.32	*	48.65	46.67	48.96	1.86
Total Acres Lost					123.75		

Acreages of Peconic Estuary Targeted Tidal Wetlands

	Targeted Wetland	1974 acreage	2002 acreage	Acres Lost	% Loss	Acres Lost/Year
Peconic Bay	Corey Creek	28.16	20.41	7.75	27.5	0.28
	Cedar Beach Creek	19.72	11.16	8.56	43.4	0.3
Total Acres Lost				16.31		

Acreages of South Shore Targeted Tidal Wetlands in Nassau and Suffolk Counties

	Targeted Wetland	1974 acreage	1998 acreage	2001 acreage	Acres Lost	% Loss	Acres Lost/Year
South	Gilgo Islands	108	*	70	38	36	1.4
Oyster Bay	Goose Island	61	46	*	15	25	0.55
Middle Bay	West Islands	527	*	404	123	23	4.5
East Bay	East Bay Islands	606	498	*	108	18	4.0
Total Acres Lost					284		

^{*} Acreage was not calculated for these years.

All wetland areas studied except the Nissequogue River (11%) greatly exceeded the 10% criteria set in the <u>marsh loss strategy</u>. While loss of tidal wetlands at the subject sites must be assessed on a case by case basis, no direct filling or dredging of the vegetated marsh was known to occur. Losses occurred for one or more of the following reasons: wave energy, erosion, sand accretion, sediment budget disruption, subsidence, dredging and sea level rise. Unlike Jamaica Bay, mussel dams were not a factor.

This preliminary expedited trends analysis focused on areas that represented qualitative losses discovered while conducting annual video and photographic inventories. While the losses are high in those target areas, they represent only those specific areas listed. The marsh loss phenomenon requires further study to determine the reasons for the losses, and the development of marsh management and restoration plans. Below are photographic comparative examples of the losses observed.

ATTACHMENT 3
(Long Island Sound Collaborative Embayment Study)

Long Island Sound Embayment Study To Determine Causes of Vegetative Tidal Wetlands Loss

The study is a collaborative effort supported/funded by a NYC Nitrogen Settlement to DEC for nitrogen violations to Long Island Sound and includes the NYS Dept. of Environmental Conservation (DEC), Stony Brook's Marine Sciences Research Center (MSRC) and the United States Geological Survey (USGS).

Tidal wetlands are one of the most productive environments in the world. They provide nutrients to our estuaries, habitat for wildlife, filter the estuary and buffer against storms. Recent trends analysis examining the effectiveness of our tidal wetlands regulations and regulatory program revealed that the regulations and the regulatory program were highly effective in stemming the tide of historic "fill and build" activities. However, the trends also revealed that tidal wetlands, specifically, low marshes, were disappearing. These studies are an attempt to define the causes.

The study will include embayments at West Pond, Glen Cove; East Creek, Manhasset; Frost Creek, Lattingtown and Flax Pond, Old Field

The first component is the tidal wetlands trends analysis. In this part, Fred Mushacke, NYSDEC, will compare historic (1974) and contemporary aerial photos that are placed in GIS (Geographic Information System) software and geo-referenced. He will then identify and compare the tidal wetlands zones from each image. (see comparison video of 1974 – 2006 infrared images, Figure 1) to determine changes.

The second component, conducted by Heather Young, DEC, is the monitoring of sediments on the surface of the marsh, specifically in the low marsh. Special devices called SETs (Surface Elevation Table; see http://www.pwrc.usgs.gov/set and Figure2) will measure the buildup or loss of sediment over time. SET analysis will be augmented by "marker horizon" measurements, Figure3, which employs feldspar or other light colored materials that are easily distinguishable from surrounding sediments and placed on the marsh surface. When simultaneously used with the SET, the marker horizons can provide information on below ground processes that influence elevation change, such as shallow subsidence (See https://www.pwrc.usgs.gov/set/theory.html#mh).

The third component, conducted by J. Kirk Cochran, PhD, MSRC, is two-fold: 1) evaluate the accretion history of the marsh over the past 100 years and compare it with long and short-term changes in sea level as well as with short-term accretion rates determined by the SETs. This involves core sampling and analysis for Pb-210 and solid phase geochemistry; 2) characterize the basic geochemistry of the marsh through analysis

of hydrogen sulfide and nutrients (N, P) in the sediment pore water and reactive iron and solid phase sulfide pools in the sediment, Figure 4&5. These elements are critical in determining whether high concentrations of hydrogen sulfide in the marsh pore waters are leading to the decrease in plant biomass and ultimately death of the marsh plant and subsidence of the marsh peat.

The fourth component, conducted by the USGS, is the continuous monitoring of water elevation in each of the four embayments. This involves the installation and operation of real-time monitoring stations which will relay the collected data hourly via satellite telemetry to USGS offices where this information will be made available via the internet within a few minutes of arrival. At two of the sites—East Creek and Frost Creek—water temperature and salinity will also be collected and, at Flax Pond, will be supplemented by monitoring for other water-quality parameters including pH, dissolved oxygen, and turbidity (Figure 6, shows a rendition of the monitoring device). All water-quality readings will be disseminated over the internet in real time through the same processes employed for the water elevations.

The ultimate goal of the project is to identify causes of vegetative tidal wetlands loss. Immediately below is the 1974 infrared inventory imagery of Flax Pond and further below is the 2006 imagery for comparison.





Figure 1. Flax Pond 1974 infrared inventory aerial over 2006 aerial infrared note changes at inlet and to large island in center of images. Vegetation is red; mudflats are silver-blue in color.



Figure 2. SET device temporarily installed to measure accretion rate at site, once measurements are taken the "head" is removed



Figure 3. Feldspar companion measurement, measures amount of sediment deposited on marsh and compared to SET measurements, to check for marsh subsidence. A rod frozen with nitrogen is used to extract the sample from the marsh peat.

Sampling strategy: Multi-port piezometer (MPP)

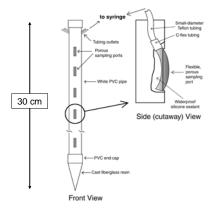


Figure 4. Sampling device implanted in the marsh to sample pore water at various depths



Figure 5. Suction devices used to collect pore water samples, these are removed and taken to the lab.



Figure 6. A rendition of what the tide monitoring station will look like attached to the Flax Pond bridge. Photo courtesy of Sandy Richard