LONG ISLAND TIDAL WETLANDS TRENDS ANALYSIS

Prepared for the

NEW ENGLAND INTERSTATE WATER POLLUTION CONTROL COMMISSION

Prepared by

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NOTICE

This report was prepared by Cameron Engineering & Associates, LLC in cooperation with Land Use Ecological Services, Inc.

Executive Summary

The purpose of the Long Island Tidal Wetlands Trends Analysis project was to quantify the magnitude of landscape-level changes in wetlands loss and changes in marsh condition within the Long Island Sound, Peconic, and South Shore Estuaries including all or parts of Westchester, Bronx, Queens, Nassau, and Suffolk Counties. (See Figure 1 and Figure 2 for the geographic extents of the study area and its estuaries, respectively.) The results of this project, the observed trends in wetland area and composition change, and implications for estuary health and supply of estuarine ecosystem services are intended for use by environmental managers, conservation advocates and elected officials across a variety of regulatory agencies, environmental organizations, and governments.

Changes, including degradation, fragmentation and severe acreage losses have been observed in several Long Island, NY tidal wetland complexes during discrete and limited trends analyses. The results of this effort support other studies that have demonstrated substantial loss of tidal wetlands area over the past forty years. Typical indicators of native marsh loss (i.e., not including *Phragmites australis* marsh) that were observed in the study area include retreat of the seaward edge of the marsh, loss of marsh islands, widening of tidal creeks and ditches, panne/mudflat, pond formation, and encroachment of invasive *Phragmites australis*. In addition to native marsh loss, conversion of high marsh to low marsh is indicative of sea level rise.

The trends analysis was conducted across the three major tidal wetland classes (i.e., Intertidal, High and Fresh Marsh) and *Phragmites australis* over two time periods: 1) Year 1974 and 2) Year 2005/2008 (current year). The current year tidal wetlands were mapped using a computer - assisted image processing technique that isolates and groups pixels within an image according to the unique reflectance values, or 'signatures', of different plant species and other marsh features. The current year tidal wetland inventory comprises the vegetated wetland areas only; unvegetated areas, such as pannes, mudflats and water bodies, were removed from the wetland map and thus are not included in the area loss/gain calculations. In a like manner, the 1974 tidal wetland inventory – which included unvegetated features within the major tidal wetland classes – was enhanced by removing unvegetated features (e.g., pannes, mudflats, and water bodies). Such enhancement allowed a one-to-one comparison between the 1974 and current year tidal wetlands. Summaries were calculated at three geographic levels, comprising the estuary, town boundary and marsh complex.

Overall, Long Island's estuaries have lost 13.1 % of native intertidal (IM), high marsh (HM), and coastal fresh marsh (FM) communities between 1974 and 2005/2008 (Table 3). Appendix II provides the results of the imagery analysis and trends in marsh area for each of the identified tidal wetland complexes. The Peconic Estuary and South Shore Estuaries have slightly lower percentages of marsh loss (-10.4% and -11.6%, respectively) compared to the Long Island Sound Estuary (-22.6%). Collectively, Long Island's three estuary complexes lost, on average, 85 acres of native marsh annually over this time. The largest loss of native marsh, i.e., 1,692 acres, occurred in the South Shore Estuary where the native marsh area declined from approximately 14,652 acres in Year 1974 to 12,959 acres in Year 2008. The native marsh in the Long Island Sound decreased by an estimated 654 acres from 2,892 acres in Year 1974 to 2,237 acres in Year 2008. Approximately 356 acres of native marsh were lost in the Peconic Estuary, declining from an estimated 3,444 to 3,078 acres from Year 1974 through 2008.

A majority of the loss of native marsh within the South Shore Estuary, i.e., 1,060 acres, occurred within the Town of Hempstead. The remaining native marsh losses within the South Shore Estuary (i.e., 599 acres) comprised approximately 120, 148, 143, and 188 acres within the Towns of Oyster Bay, Babylon, Islip, and Brookhaven, respectively (Table 16). Within the Town of Southampton, the South Shore Estuary native marsh area increased by 63 acres. Within the Long Island Sound Estuary, The largest losses in marsh area from 1974 to 2005 occurred in the Towns of Huntington (163.6 acres lost), Smithtown (132.8 acres lost), Brookhaven (67.0 acres lost), and North Hempstead (44.5 acres lost); in addition, the Bronx lost an estimated 77.8 acres of native marsh Table 31).

The Peconic Estuary spans the Towns of East Hampton, Riverhead, Shelter Island, Southampton and Southold. East Hampton sustained the largest loss of marsh habitat, losing 145.8 acres for a

13.8 percent decrease from 1974 to 2005. The Town of Southold lost nearly 10 percent of marsh habitat from 1974 through 2005, while the Town of Riverhead exhibited a slight gain in native tidal wetland area. The highest percentage loss of marsh habitat occurred in the Town of Shelter Island where marsh habitat decreased in area by 17.5 percent.

Each marsh complex was identified as “stable”, i.e. less than 10% decrease or increase in marsh area between 1974 and 2005/2008, or “at-risk”, i.e. more than 10% loss in marsh area. In the South Shore Estuary, the trends analysis identified 117 ‘At-Risk’ marshes complexes – out of a total of 215 (Table 26). The number of ‘At-Risk’ marsh complexes and proportion of marsh complexes identified as ‘At-Risk’ declined eastward within the South Shore Estuary. The trends analysis identified 100 ‘At-Risk’ marsh complexes – out of a total of 152 – in the Long Island Sound Estuary (Table 36). 86 ‘At-Risk’ marshes – out of a total of 159 – were identified within the Peconic Estuary (Table 43). ‘At-Risk’ marshes are located throughout the estuary; however, clustering is apparent in the western portions of the estuary, particularly adjacent to more developed areas around Riverhead, Sag Harbor and along the north shore of Peconic Bay.

The major changes in the biological and physical structure of Long Island’s marshes observed in this study include:

- Conversion of High Marsh to Intertidal Marsh
- Formation of Pannes and Ponds Within Marshes
- Conversion of Intertidal Marsh Islands to Mudflats
- Widening of Tidal Creeks and Man-made Ditches

- Erosion and Retreat of Seaward Edge, and
- *Phragmites australis* Encroachment

Both the conversion of high marsh to intertidal marsh and the formation of expansive panne and pond areas within marshes are indicators of marsh drowning or waterlogging. Marsh drowning may be due to the interacting effects of the failure of marsh accretional processes (such as deposition of organic sediments and accumulation of plant biomass) to keep pace with relative sea level rise and marsh subsidence related to plant mortality and subsequent decomposition of root biomass (Fagherazzi et al, 2012; Kirwan and Megonigal, 2013). This failure is due to physiological stresses such as increased flooding, sulfide accumulation, and nutrient enrichment (Turner et al, 2009; Wigand et al, 2014).

Many wetland complexes with large losses of high marsh habitats through marsh drowning and subsidence exhibit large gains in intertidal marsh as shown in Table 5, which presents the marsh area change for each of the complexes identified in Table 3, and Table 6, which presents the marsh complexes with the largest observed gains in intertidal marsh area. In contrast, other marsh complexes with large losses of high marsh habitats exhibited large reductions in total marsh area and due to the conversion of high marsh to pannes, marsh ponds, and open water, as shown at Timber Point (ID # 431, Figure 9). Wetland complexes showing significant losses in intertidal marsh, either in acreage or percent loss, are predominantly located in the western South Shore estuary (acreage) or Long Island Sound (percent loss) (Table 9 and Table 10, respectively). Considered in conjunction with the observed losses of high marsh, the observed trends in intertidal marshes indicate that substantial subsidence/drowning of tidal marshes is occurring throughout Long Island's three major estuary systems.

Comparison of the 1974 and 2005/2008 aerial imagery indicates widening of natural tidal creeks and man-made ditches in many Long Island marsh complexes. Creek widening in other degrading marshes in the northeastern United States has been attributed to reduced structural integrity and collapse of creek banks resulting from reduced root biomass, increased decomposition of organic matter, and increased soil water content (Deegan et al, 2012) and, in some cases, herbivory from *Sesarma* crabs (Smith, 2009). Creek width and cross-sectional area is related to the geomorphological and hydrological characteristics of the marsh and surrounding estuary and, as a result, may be impacted by changes in tidal prism (Vandenbruwaene et al, 2013) resulting from relative sea level rise (Stefanon et al, 2012) or anthropogenic changes in inlet or estuary bathymetry. Creek banks, particularly in large tidal channels, may also be subject to erosional forces from wind-driven waves during storms, greater water flow rates, and vessel wakes.

Many marshes in Long Island's estuaries exhibit pronounced retreat of the seaward marsh edge. The recession of marsh edges is influenced by similar processes to bank collapse and widening. However, due to their less sheltered position, marsh edges are subjected to greater erosional forces from vessel wakes and during storms. In addition, other anthropogenic disturbance of the seaward edge of the marsh such as the harvesting of ribbed mussels from the marsh or harvesting of shellfish from the subtidal mudflats adjacent to *Spartina alterniflora* may also affect the stability of the seaward edge of the marsh and *Spartina* recruitment.

Invasive *Phragmites australis* has colonized large areas of high marsh and coastal fresh marsh habitats on Long Island. However, many of Long Island's marshes were infested by *Phragmites australis* prior to 1974. Long Island's estuaries exhibit different trends regarding *Phragmites australis* abundance (Table 12). In the Long Island Sound, Peconic Estuary, and the coastal bays in Southampton and East Hampton, *Phragmites australis* encroachment has contributed to the drastic loss of native high marsh communities and led to the near eradication of areas classified as coastal fresh marsh. *Phragmites australis* has continued to colonize high and coastal fresh marshes within the South Shore Estuary. However, overall *Phragmites australis* coverage within the South Shore Estuary has decreased by 11.9% due to the loss of *Phragmites australis* on former dredge spoil sites west of Fire Island Inlet and in Moriches and Shinnecock Bays.

Salt marshes provide many critical benefits to human communities including fish and shellfish production, protection of shorelines from coastal storms, erosion control and sediment stabilization, water filtration through nutrient and sediment removal, carbon sequestration, and recreation and tourism (Barbier et al, 2011). The loss of nearly 3,000 acres of native wetlands implies a substantial loss of ecosystem services in Long Island's estuaries. The approximately 30% loss of high marsh habitats, in particular, throughout Long Island between 1974 and the mid 2000‟s and resulting loss of ecosystem services and habitat for wildlife and rare plants demands restoration efforts in complexes with greatest losses of high marsh area (Table 5) and increased management in the largest remaining high marshes (Table 6).

Tidal wetlands provide many critical benefits to human communities including fish and shellfish production, protection of shorelines from coastal storms, erosion control and sediment stabilization, water filtration through nutrient and sediment removal, carbon sequestration, and recreation and tourism (Barbier et al, 2011). The loss of nearly 3,000 acres of intertidal marshes, high marshes, and coastal fresh marshes (13.1% of the 1974 wetland area) implies a substantial loss of ecosystem services in Long Island's estuaries. The approximately 30% loss of high marsh habitats is particularly alarming due to the loss of habitat for wildlife, high marsh-nesting birds, and rare plants endemic to high marshes. The tidal wetlands losses documented in this project and the resulting loss of ecosystem services and habitat for wildlife and rare plants demand increased management in the largest remaining marshes and implementation of restoration efforts in complexes with greatest losses of marsh area and other suitable restoration locations. Restoration and management efforts could include, but not be limited to, re-establishment of native marsh vegetation in areas where native vegetation has been lost to mudflat or panne formation, Phragmites encroachment, historical filling, or hydrological perturbation; protection of existing marshes from erosional losses; and actions to allow existing marshes to adapt to rising sea level.

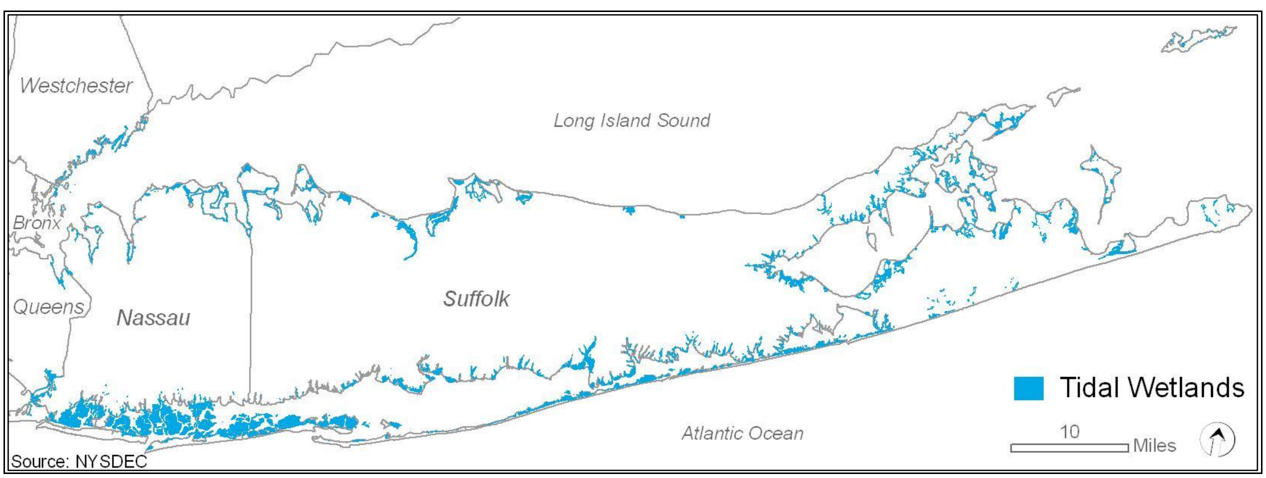
Introduction

Purpose

The purpose of the Long Island Tidal Wetlands Trends Analysis project was to quantify the magnitude of landscape-level changes in wetlands loss and changes in marsh condition within the Long Island Sound, Peconic, and South Shore Estuaries including all or parts of Westchester, Bronx, Queens, Nassau, and Suffolk Counties. The project study area is depicted in Figure 1. The results of this project, the observed trends in wetland area and composition change, and implications for estuary health and supply of estuarine ecosystem services are intended for use by environmental managers, conservation advocates and elected officials across a variety of regulatory agencies, environmental organizations, and governments. Identification of small spatial scale variation in marsh composition (i.e. less than approximately 100 square feet in area), while of ecological importance due to habitat complexity, was given lower priority under this project than providing landscape-level trends on Long Island’s tidal wetlands that can be used by regulatory agencies, environmental organizations, and governments. This work is not related to any specific environmental regulation or any specific regulatory decisions.

The project utilized Geographic Information System (GIS) and image analysis tools coupled with field reconnaissance to quantitatively and qualitatively assess Long Island's current tidal wetlands. The delineation of current tidal wetlands is based upon the image classification of the most recently available high-resolution, color-infrared aerial photography. The current year delineation is compared with a similar assessment of tidal wetlands that was generated in Year 1974 via photo-interpretation of images taken in the same year. The comparison of the current and Year 1974 tidal wetlands areas, i.e., a quantitative trends analysis, was conducted across 527 wetland complexes, three major estuaries (i.e., Long Island Sound, Peconic and South Shore) and selected local government boundaries.

Figure 1: Project Study Area



Environmental and Ecological Context

New York's diverse coastal wetlands and their ecosystems are biologically, ecologically, economically, and recreationally valuable. These wetlands protect coastal water quality by acting as a sink for land derived nutrients and contaminants, constitute an important component of coastal food webs, provide valuable wildlife habitat, and protect upland and shoreline areas from flooding and erosion.

Alarming changes, including degradation, fragmentation and severe acreage losses have been observed in several Long Island, NY tidal wetland complexes during discrete and limited trends analyses. In order to begin to develop and implement advanced protection and restoration initiatives and policies, these changes must be studied in depth. The primary goal of the Long Island Tidal Wetlands Trends Analysis was to assess the quantitative and qualitative changes, including the extent of marsh acreage lost or gained, and changes or shifts in tidal wetland vegetation since the last New York State regulatory inventory of 1974.

The study area for this project includes coastal areas of New York State within the Long Island Sound, Peconic, and South Shore estuaries including all part or parts of Westchester, Bronx, Queens, Nassau, and Suffolk Counties (see Figure 1). Trends were assessed on the individual marsh complex scale, and within and between each estuarine system.

The results of this effort support other studies that have demonstrated substantial loss of tidal wetlands area over the past forty years. Typical indicators of native marsh (i.e. not including *Phragmites australis* marsh) loss observed include retreat of the seaward edge of the marsh, loss of marsh islands, widening of tidal creeks and ditches, panne/mudflat and pond formation, and encroachment of invasive *Phragmites australis*. In addition to native marsh loss, conversion of high marsh to low marsh is indicative of sea level rise.

Funding Source and Partners

This project was funded by the New England Interstate Water Pollution Control Commission (NEIWPCC), the U.S. Environmental Protection Agency (US EPA), the New York State Department of Environmental Conservation (NYS DEC), and The Nature Conservancy (TNC). The project was administered by the NEIWPCC and representatives from the US EPA, the NYS DEC and TNC provided technical guidance under the auspices of a Technical Advisory Committee (TAC). The TAC met regularly to review project progress and findings. Representatives from the Suffolk County Departments of Health Services and Environment and Energy and the Town of East Hampton Planning Department also served on the TAC.

Trends Analysis

This trends analysis compared tidal wetland areas in the study area over two time periods: 1) Year 1974 and 2) Year 2005/2008. Appendix I provides index maps showing the location and Complex ID # for each identified tidal wetland complex. The tidal wetland boundaries for the first time period were established in 1974 via manual photo-interpretation of color-infrared imagery. Photo prints of the original pen-on-photo delineations serve as the New York State Official Tidal Wetlands Inventory. The official 1974 tidal wetland boundaries were eventually digitized – from scans of the official maps – for use with a GIS.

The tidal wetland delineation for the second time period in the trends analysis was generated from two sets of readily available color-infrared imagery for Years 2005 and 2008. The Year 2005 imagery encompassed the marsh habitat, shorelines and adjacent upland areas for the Long Island Sound and Peconic Estuaries. The Year 2008 imagery covers the entirety of the South Shore Estuary and vicinity. The tidal wetlands of the three estuaries are shown in Figure 2.

The Year 2005/2008 tidal wetland mapping – referred to as the “current year” delineation for the purposes of this study – was generated via image classification. Image classification is a computer-assisted technique which classifies pixels of a raster image based on the spectral reflectances of plant species and other natural features. This method is based on the principle that every plant species exhibits a unique spectral response to solar radiation across the electromagnetic spectrum. (Note: In practice, specific bands are established for image classification purposes wherein reflectance values are averaged; this can cause the reflectance values of species to overlap.)

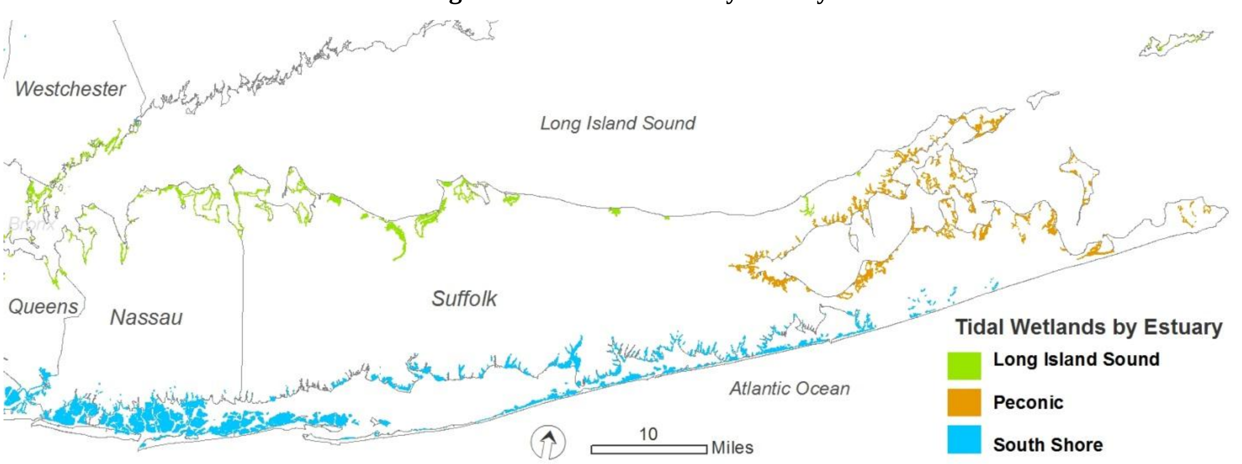
The unique spectral response of each wetland species was employed to classify each color-infrared image into species or species group for low marsh, high marsh, and *Phragmites australis*. Upland plant species and other marsh features (e.g., mudflats, salt pannes and water) were also classified based on their unique spectral signatures. New York’s tidal wetlands contain a variety of unvegetated or sparsely vegetated substrates such as sand, gravel, or cobble beaches, salt pannes (which often contain various densities of plant such as *Salicornia sp*. and *Limonium caroliniana*), and mudflats located seaward of or in between vegetated marsh areas. Due to the absence or low density vegetation on these substrates, the image classification used in this study cannot differentiate between traditional salt pannes and marshes that have lost vegetation due to die-off or subsidence. In addition, while unvegetated surfaces, such as mudflats and pannes, can be differentiated from standing water, reliable conclusions cannot be reached by quantifying and analyzing the areas of unvegetated surfaces and standing water in the aerial imagery as the observed boundaries between unvegetated and water surfaces are arbitrary and dependent on recent rainfall, lunar phase (spring versus neap tide), and when in the tidal cycle the aerial imagery was collected. These factors may influence if a panne has some standing water in it or not or if a creek has or does not have exposed mud within its channel.

Classified species/species groups were ultimately reclassified into tidal wetland classes (i.e., intertidal marsh, high marsh, and coastal fresh marsh) based on definitions contained in the New York State Tidal Wetlands Land Use Regulations (Part 661). More detailed classifications of the ecological community types recognizing the diversity of habitat and species assemblages in New York State's tidal wetlands have been developed since the promulgation of Part 661, such as Reschke (1990), Edinger et al. (2002), and Sneddon and Lamont (2010). However, the tidal wetland mapping classes contained in Part 661 were utilized for this study in order to facilitate comparison with the 1974 New York State Tidal Wetlands Inventory Maps. A detailed methodology for the image classification technique is provided in the "Methodology and Data" section below.

The trends analysis was conducted across the three major tidal wetland classes (i.e., Intertidal, High and Fresh Marsh) and *Phragmites australis* and at three geographic levels, comprising – in order of decreasing geographic extent – the estuary, town boundary and marsh complex. The trend for a particular tidal wetland class is calculated by subtracting the Year 1974 area from the current year area; the change in area according to this formula can be negative or positive. If negative, the change indicates a loss of wetland for that class during the period from Year 1974 to the current year. Likewise, a positive change value indicates a gain in wetland during the same time period. The change is also calculated at the marsh complex scale to determine the total change in marsh area (i.e., comprising the three tidal wetland classes) from Year 1974 to the current year.

The estuary level is utilized as practical framework for presentation and discussion of the trends. Some results are also presented by Town to provide information to municipal land managers and regulators and to convey general information on geographic position and environmental conditions. Also, the organization of results by Town also facilitates interpretation of data tables by avoiding the presentation of large sets of results, such as the At-Risk Marshes tables, solely by alphabetical order or Complex ID #.

Figure 2: Tidal wetlands by estuary



Methodology and Data

Outline of Technical Approach

The trends analysis consisted of a comparison of four broad tidal wetland classes (i.e., Intertidal Marsh, High Marsh, Coastal Fresh Marsh and *Phragmites australis*) over two time periods. The first time period was Year 1974, when the first tidal wetland mapping was conducted. The second time period was termed the 'current year' for the purposes of this study despite the acknowledgement that the color-infrared photos were taken in Years 2005 and 2008. The current year tidal wetlands were mapped using a computer-assisted image processing technique that isolates and groups pixels within an image according to the unique reflectance values, or 'signatures', of different plant species and other marsh features.

Given a standard spectral library and the repeatability of a classification algorithm, the computer-assisted approach is, arguably, more consistent than the manual interpretation method employed for the 1974 tidal wetland delineation. The computer-assisted approach also easily identified and extracted numerous salt pannes, water bodies and other unvegetated areas (e.g., mudflats) within the image tiles, features that could not easily be delineated manually. Furthermore, the 1974 imagery were not orthorectified at the time of the manual delineation or prior to this project. As a result, a previous digitizing of the 1974 tidal wetland boundaries sustains sizable errors in position and shape, the latter of which affects the true area of a wetland polygon. Thus, the tidal wetland delineations from the two time periods have important differences. The methodology utilized in this project corrects for these differences, thus achieving a greater degree of equivalence, i.e., reduces difference in delineation accuracies, between the Year 1974 and Current Year delineations. Such efforts were important to the accuracy of the trends analysis.

An error analysis, that examines the relative difference between the computer-assisted and manual delineations approaches, was also conducted. This comprised the application of the computer-assisted tidal wetland image classification to randomly selected 1974 image tiles. Specifically, this analysis compares the mapped areas of the intertidal and high marshes for the manual 1974 photointerpretation and the computer-assisted wetland classification. With this 'error' analysis, the effect of the relative difference between the two approaches on the trends analysis was estimated.

Technical Objectives

The compilation of an accurate tidal wetlands trends analysis was accomplished through the stepwise completion of several technical objectives, or tasks, which comprised the following:

1. Identification of discrete wetland complexes

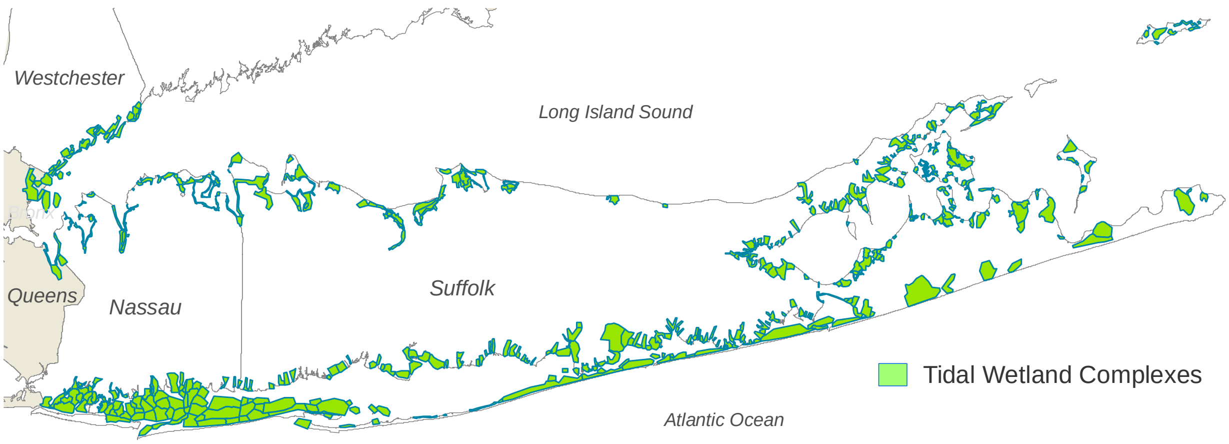
2. Scanning, orthorectification (removal of image tilt and terrain to create planimetrically correct image) and tonal balancing/mosaicking of color-infrared imagery
3. Field reconnaissance to identify and groundtruth wetland and other plant species
4. Classification of color-infrared imagery via application of a spectral library
5. Vectorization (conversion of raster classification files to vector shapefiles) and delineation of current wetland boundaries
6. Enhancement of Year 1974 tidal wetland boundaries
7. Trends Analysis
8. Error Analysis (classification error and calculation of relative difference)

It is important to note that the objective of this project was to produce tidal wetlands mapping for the current year and an enhanced version for Year 1974 that was sufficient for trends analysis. Thus, the accuracy of the current year tidal wetlands mapping is not equivalent to that achieved by field delineations. Typical mapping accuracies for automated image classifications ranges from 75 to 85 percent depending upon the classification technique employed (Thakur et al., 2012). However, the current year tidal wetlands mapping accuracy exceeds typical classification accuracies owing to the collection of numerous groundtruthed data points (i.e., for tidal wetland and other plant species) and post-classification corrections through heads-up digitizing.

Identification of discrete wetland complexes

The project team identified tidal marsh complexes using a classification system based on the Significant Coastal Fish and Wildlife Habitats (SCFWHs) identified by the New York State Coastal Atlas (NYS Department of State, 2002). Appendix I provides index maps showing the location and Complex ID # for each identified tidal wetland complex. Appendix II provides the results of the imagery and trends analysis of each of the identified tidal wetland complexes. Marsh complexes were identified and mapped in a geographically contiguous manner and delineated such that environmental impacts and indicators of marsh loss would be expected to be relatively uniform within the complex. Accordingly, many SCFWHs were subdivided into independent marsh complexes due to the large size of the SCFWHs and the disparate environmental conditions or impacts within SCFWHs. In addition, it was necessary to differentiate between marsh islands and nearby upland fringe marshes within identified marsh complexes.

Figure 3: Marsh Complexes of the Study Area



The identification of discrete wetland complexes recognized that not all tidal wetlands within the project area are located within SCFWHs as they are under federal jurisdiction (e.g., Oyster Bay National Wildlife Refuge, Fire Island National Seashore), Native American tribal ownership (e.g., Shinnecock Indian Reservation) or experienced previous adverse environmental impacts (e.g., Quantuck Bay, Meetinghouse Creek). All marsh complexes within these SCFWH-excluded areas were selected for inclusion in the trends analysis. Based on these parameters, 527 marsh complexes were identified; the boundaries of the complexes are depicted in Figure 3.

The project team also recognized that some SCFWHs contain freshwater wetland habitats (e.g., Nissequogue River, Long Pond Greenbelt) and upland habitats (e.g. Grandifolia Sandhills, Southampton Beach and Dunes). Upland or freshwater wetland portions of SCFWHs were not included within the tidal wetland complexes. Each wetland complex was named and assigned the following identifiers within the GIS project database: County, Town, SCFWH, and NYS Tidal Wetland Inventory Map Number(s).

Scanning, orthorectification, and normalization of color-infrared imagery

Imagery utilized for this trends analysis project consists of Year 1974 color-infrared photographs (employed for the first tidal wetland delineation), Year 2005 color-infrared imagery for the Long Island Sound and Peconic Estuaries, and Year 2008 color-infrared imagery for the South Shore Estuary. The Year 2008 color-infrared imagery was digitally scanned, orthorectified and mosaicked to a 2,000 meter by 2,000 meter image tile grid under a previous effort by TNC. Year 1974 and 2005 imagery, however, were not previously scanned and orthorectified and were processed in a manner comparable to the Year 2008 imagery.

The accuracy of the tidal wetland mapping conducted for this project was dependent upon the proper processing of the color-infrared imagery and its accurate orthorectification. To this end, adequate image processing parameters were established. The color-infrared imagery for Years

1974 and 2005 were scanned at a resolution of 1,000 dpi. Scanning at this resolution provided digital images with 1-foot resolution, comparable to (or exceeding) the Year 2008 aerial imagery previously compiled for the South Shore. The 1,000-dpi scan also reduced the degree of pixel mixing (averaging of pixel values that occurs for larger pixel sizes) for spectral analysis and facilitated easier and quicker differentiation between vegetation types when conducting quality control reviews.

It is noted that not all of the 1974 color-infrared images for Long Island needed to be scanned. Instead, only the 1974 images that were essential for mapping vegetated wetlands were scanned and orthorectified. 493 image tiles – from a total inventory of approximately 2,000 images – were ultimately scanned for Year 1974; the remaining image tiles contained no vegetated tidal wetlands. In addition, four of the tiles that were required for Year 1974 were missing from the image inventory.

The 1974 and 2005 images were scanned using the Wehrli RM3 or RM4 scanner. The RM-3 and RM-4 scanners are capable of scanning cut sheet or roll film media with a geometric accuracy of +/- 3 micron RMSE (root mean square error) without resampling the image data. The Wehrli scanners featured a computer controlled LED illumination system that is radiometrically calibrated across the sensor elements. The instrument utilizes a 12-Bit tri-linear sensor and an 8 micron (3,175 dpi maximum) optical system.

The orthorectified Year 2005 color-infrared imagery was also normalized and mosaicked into a 2,000-meter by 2,000-meter image grid. This grid is comparable to the original 1974 grid in terms of tile dimensions, however, the original grid utilizes a previous coordinate system based on the North American (Horizontal) Datum of 1927 (NAD27). To be current with a contemporary datum, the new grid utilizes the current North American Datum of 1983 (NAD83). (The Year 2008 imagery for the South Shore was also established in NAD83). Thus, the original NAD27 tidal wetland grid and the new NAD83 grid used for recent imagery do not coincide.

In addition, image normalization, which includes dynamic range adjustment (adjustment of the ratio between maximum, i.e. white, and minimum, i.e. black, light intensities), tonal balancing (brightness and contrast), and color-balancing, was conducted in accordance with best practices prepared for the National Agriculture Imagery Program (NAIP), a nationwide photogrammetry program of high-resolution imagery used to map farmlands and to distinguish between crop types (USDA, 2007).

The orthorectification process employed proprietary ground control points and a high-resolution digital-elevation model. The orthorectification process attained a positional accuracy that did not exceed 3 feet of root mean square error.

Field reconnaissance to identify and groundtruth wetland and other plant species

The tidal wetland classification and delineation was supported and complemented by rigorous field reconnaissance, groundtruthing and error analysis. Field data collection was performed using a Trimble GeoXH 6000 Series receiver and post-processed to attain an accuracy ± 0.5m. Data points were collected for species having a patch size greater than 5 meters to minimize the potential for change in species from the 2005/2008 images to 2011/2012 data collection. In addition to GPS location and species identification recorded in the GIS database, the following information was recorded on a data collection form: photograph with cardinal direction, percent relative cover, patch size, plant height and growth form, and physical indicators of marsh loss.

A total of 912 data features were collected for this project throughout the study area. The field effort resulted in the collection of 805 data points for use in image classification and error analysis. (The use of groundtruthed species locations – which establishes "training points" and "test points" for image classification and error analysis, respectively – is discussed below.) Additionally, 74 area features and 29 line features – which were located at the boundary of marsh types – and 4 generic/upland data points were collected for reference purposes.

Table 1: Summary of field data points collected by Town

Town	% Points Required	Max. # Points	% Points Collected	# Points Collected
East Hampton	Up to 15%	146	4.18%	34
Southampton	Up to 21%	205	8.48%	69
Shelter Island	Up to 11%	107	3.81%	31
Southold	Up to 15%	146	4.05%	33
Riverhead	Up to 11%	107	1.11%	9
Brookhaven	4-24%	234	17.81%	145
Islip	Up to 16%	156	7.74%	63
Babylon	Up to 20%	195	6.02%	49
Smithtown	Up to 13%	127	2.70%	22
Huntington	Up to 13%	127	4.18%	34
Oyster Bay	Up to 16%	156	11.18%	91
North Hempstead	Up to 11%	107	0.00%	0
Hempstead	22-42%	410	23.71%	193
Queens	Up to 12%	117	0.25%	2
Bronx	Up to 10%	98	1.35%	11
Larchmont			1.11%	9
Mamaroneck	Up to 10%	98	0.00%	0
Rye	Up to 11%	107	1.23%	10
New Rochelle	Up to 10%	98	0.00%	0
Total # Data Points Collected				**805**

Field data collection was performed throughout the project area based on the relative Year 1974 marsh area by Town. Table 1 provides a summary of data points collected by Town, and includes the required number of points.

The field data collection effort targeted species predominately observed in each of the three vegetated marsh types as well as species commonly observed at or near the marsh boundary, as described below and summarized in Table 2:

- Intertidal Marsh – *Spartina alterniflora*
- High Marsh – *Spartina patens*, *Distichlis spicata*, *Juncus gerardii*, *Iva frutescens*
- Coastal Fresh Marsh – *Typha angustifolia*, *Schoenoplectus* spp.
- Upper High Marsh/Upland Border Species – *Phragmites australis, Baccharis halimifolia, Panicum virgatum, Morella pensylvanica, Toxicodendron radicans, Ammophila breviligulata*
- Mixed Species – Data were collected for mixed intertidal and high marsh species stands.

Table 2: Total number of data points collected by species / habitat type

Species	# Points
Spartina alterniflora	153
Spartina patens	72
Distichlis spicata	68
Juncus gerardii	20
Iva frutescens	70
Baccharis halimifolia	72
Phragmites australis	69
Typha angustifolia	11
Scheonoplectus spp.	13
Panicum virgatum	36
Morella pensylvanica	39
Toxicodendron radicans	26
Ammophila breviligulata	29
Mixed species	104
Salt panne	18
Other	5
Total # of Data Points	**805**

Classification of color-infrared imagery via application of a spectral library

The photointerpretation process for mapping the wetland boundaries comprised two major phases, i.e., supervised classification of vegetation types and other features (e.g., water bodies and salt pannes) and the grouping of vegetation types into tidal wetland classes. During the first phase of the photointerpretation process, i.e., supervised classification, spectral analysis was used to identify and differentiate among the various wetland categories.

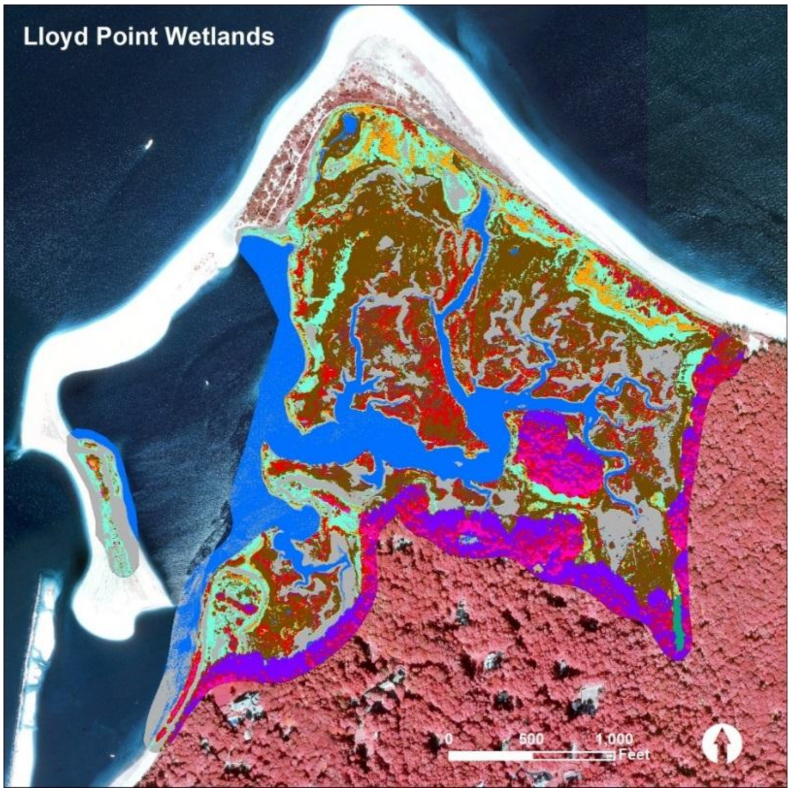
Spectral analysis is an image processing technique that is used to identify vegetation types as well as broader land cover classes by their spectral signature, i.e., by unique combinations of reflectance values within the spectral bands that comprise a false-color infrared image. Spectral analysis of the false-color infrared images that comprise the study area was performed with ENVI image analysis software. ENVI is among the most popular image analysis software packages used by remote sensing experts, scientists and researchers. ENVI provided all of the image analysis functionality required for this project including spectral analysis, image correction, 'noise removal', and feature extraction. In addition, ENVI allowed the integration of GIS data with the raster-based color-infrared imagery, a functionality that is critical to the supervised classification process discussed below.

It is important to note that supervised classification of the color-infrared image tiles – which provides an automated method for identifying tidal wetland species – resulted in improved identification of wetlands as compared with the 1974 wetlands inventory. Thus, an overestimate of the increase in wetland area from 1974 through the current year has resulted in some wetland complexes, particularly those in Moriches and Shinnecock Bays.

Figure 4 provides an example of an image classification for the tidal wetland complex known as the Lloyd Point Wetlands (Huntington). The graph below the Lloyd Point Wetlands map in Figure 4 plots the reflectance value (i.e., a measure of the light reflected back from the particular plant species) for red light versus that for near-infrared light. Each cluster of identically colored points represents the range, or envelope, of reflectance values, according to a given species' response to red and near-infrared light. Note that each plant species or marsh feature occupies its own unique region on the graph (though some overlap occurs with adjacent species owing to varying plant health conditions from low to high vigor). The characteristic set of responses, or signature, of each species to two or more given wavelengths allows the image classification algorithm to identify pixels in an image as belonging to a group of reflectance values or class, e.g., *Iva frutescens, Phragmites australis, Spartina alterniflora,* etc.). In particular, this project utilized the Maximum Likelihood classification algorithm, one of a number of automated, statistical approaches for determining the appropriate class for a pixel that near the boundary zones between classes.

The Maximum Likelihood classification methodology was employed as it attained the best matches with the field-collected test points, i.e., groundtruthed data points which are used for error analysis of the image classification. In addition, although numerous other classification algorithms (e.g., Parallelepiped Classifier, Minimum Distance, Spectral Angle Mapper and Mahalanobis Distance), have been developed and perform reasonably well, the Maximum Likelihood classification algorithm is one of the most widely used techniques (Li et al., 2014). Furthermore, it is the most powerful technique where accurate groundtruthed data points – such those acquired through this project's field reconnaissance effort – are provided (Perumal and Bhaskaran, 2010).

Figure 4: Lloyd Point Wetlands



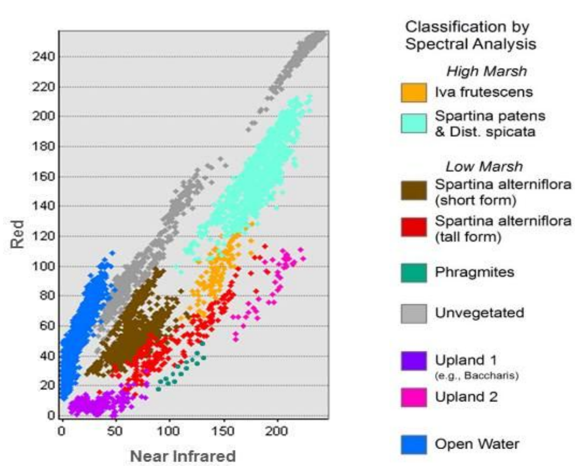
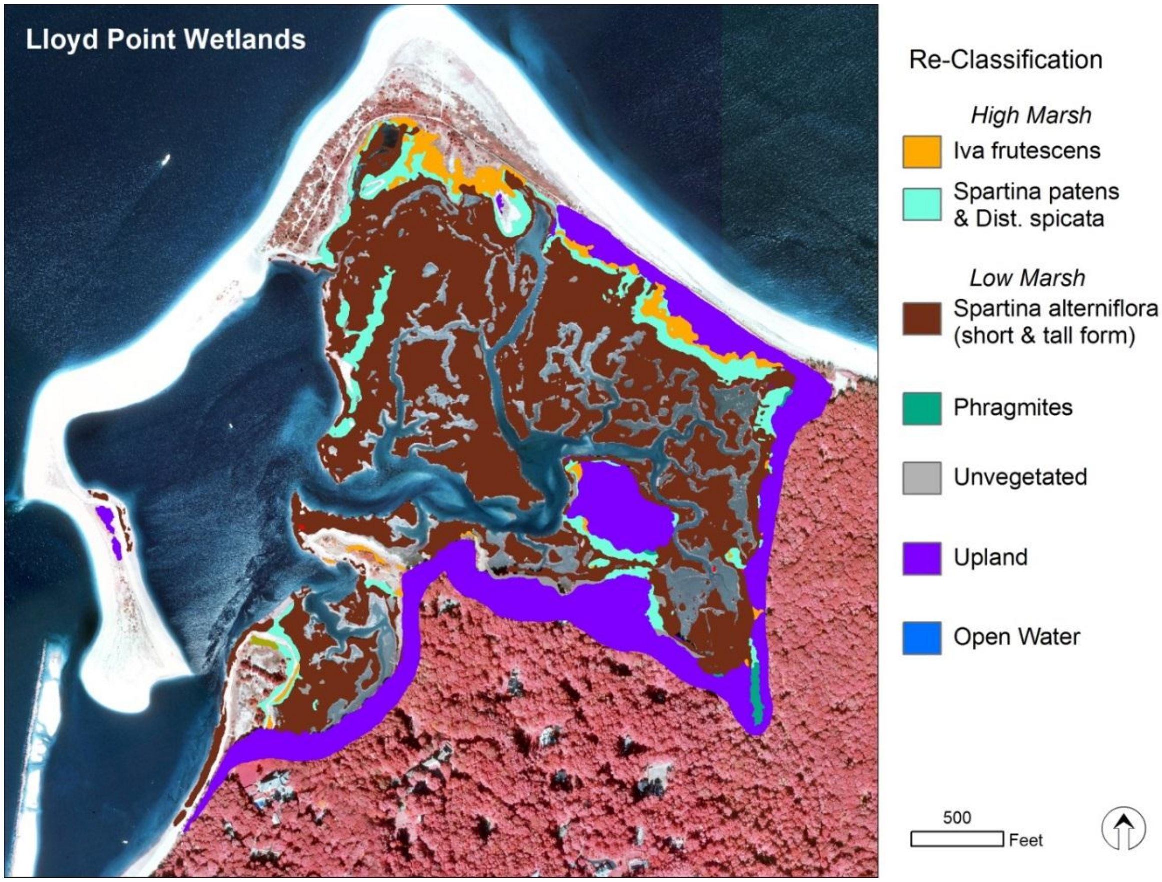


Figure 5: Lloyd Point Wetlands (Detail View)



Following the image classification as shown in Figure 4, the classified raster image was converted to a vector GIS shapefile which establishes the tidal wetlands map spatial data format. Once checked for accuracy, species and species groups were then regrouped into fewer classes as shown in Figure 5. For example, the short and tall form *Spartina alterniflora* were regrouped into one *Spartina alterniflora* class, and the two upland classes were regrouped into one upland class.

As a preparatory step to supervised classification, all digital images were tested for spectral equivalence. Images were determined to be spectrally equivalent when features in a reference, or master, image exhibited the same spectral reflectance range as those in another image, termed a servant image. (Note: the master image covered a large marsh that represented all of the species types in the spectral library and in significant quantities.) For the master and the servant image to be spectrally equivalent, the spectral ranges must match across a range of dark to bright objects, e.g., from dark water bodies, to medium brightness vegetation types to very bright (i.e., highly reflective) sandy shorelines. Thus, in the cases where the spectral reflectance ranges of features in the servant image differed substantially such that classification accuracy was reduced, i.e., more than 3 percent, from those in the master image, image normalization was conducted on the servant imager or, alternatively, the spectral library was adjusted by the difference between the master and servant images. The latter technique was utilized if, in certain instances, the differences between the master and servant image (i.e., along the gradient of light to dark spectral values) were clearly non-linear. In such instances, the spectral library was more readily adjusted than the servant image.

There were also numerous instances where the spectral values for a given species varied substantially within the image. In such instances, the image was segmented into two or more separate images for classification purposes. Each segment was then individually normalized to the master image in order to properly apply the spectral library. Such normalization and image segmentation operations posed significant analysis and computing requirements to the project but were necessary to achieve accuracy goals established in the Quality Assurance Project Plan.

This project utilized an image normalization method developed by Schott et al. (1988). Under this approach, the master and servant images were normalized by analyzing features that were statistically invariant such as concrete, asphalt pavement, rooftops, dry sand and deep water. Such features, termed “pseudo-invariant”, were not expected to exhibit different spectral ranges from one image to another; digital values of the servant image were then statistically corrected to match the master image. Once the images were tested and/or corrected for spectral equivalence and the spectral signatures of the entire library features were adequately defined (i.e., through field-collected training sites), the supervised classification procedure was conducted.

Classified images were post-processed using ENVI ‘noise reduction’ utilities including the ‘Sieve’, ‘Clump” and ‘Majority/Minority Analysis” tools. These were used to reduce the number of stray raster cells, i.e., pixels of different value within a cluster of like values. A closer examination of the classified image in Figure 4 reveals stray cells, e.g., pixels representing small patches of *Spartina patens* or *Iva frutescens* within a larger area of *Spartina alterniflora*. Utilizing the ENVI noise reduction tools, stray cells were assigned new values that were more consistent with their surrounding values. This step also simplified the raster image so that a manageable vector version of the image was generated (i.e., one with an optimal number of vector polygons for establishing tidal wetland classes.)

The development of the spectral library of features was essential to the classification process. The locations of individual plant species – collected through “groundtruthing” and termed “training points” (or “training sites”) – were used to “train” the images into classes vis-à-vis the library of spectral signatures through supervised classification.

The corrected features extracted via supervised classification were then grouped into final tidal wetland classifications according to the predominant vegetation types found within the four vegetation categories and upland borders as follows:

- **Intertidal Marsh**: Training sites were located and recorded for *Spartina alterniflora* across its variation in growth forms (i.e. tall form versus short form) and culm density.

- **Native High Marsh**: Training sites were located and recorded for stands of *Spartina patens*, *Distichlis spicata*, *Juncus gerardii*, *Iva frutescens*, and mixed-species stands. Stands dominated by short-form *Spartina alterniflora*, when found within the native high marsh, were classed as Intertidal Marsh, i.e., for patches larger than approximately 100 square feet; smaller patches of *Spartina alterniflora* were classed as High Marsh. This is consistent with the New York State Tidal Wetland Inventory Final Report mapping conventions which characterized stands predominantly comprised of short-form *Spartina alterniflora* was intertidal marsh and only included short-form *Spartina alterniflora* in high marsh when it occurred in mixed association with *Spartina patens* and/or *Distichlis spicata* (Martin et al. 1975). *Baccharis haliminfolia* was classified as upland except in instances where it was mixed and dominated by one or more of the high marsh species listed here.

- ***Phragmites australis***: Training sites were located and recorded for *Phragmites* stands including its growth forms (i.e., high vigor versus low vigor forms).

- **Native Coastal Fresh Marshes**: Training sites were located and recorded for narrow-leaved cattail (*Typha angustifolia*) and bulrushes (*Schoenoplectus* sp.). No other species were recorded for coastal fresh marshes.

- **Upland Borders**: Training sites were located and recorded for plants typically found on the landward edges of tidal wetlands including groundsel tree (*Baccharis halimifolia*), beach grass (*Ammophila breviligulata*), switchgrass (*Panicum virgatum*), poison ivy (*Toxicodendron radicans*), and northern bayberry (*Morella pensylvanica*). These plant species were selected because they are commonly observed in mixed herbaceous-shrub upland habitats which are likely to be difficult to differentiate between the adjacent mixed herbaceous habitats present in native high marshes. Note that *Baccharis halimifolia* was treated as an upland species unless mixed native high marsh species listed above.

Other features within and adjacent to marshes, such as mudflats, salt pannes, ponds, and channels/ditches, were identified. Training points were collected for salt pannes, but not for mudflats or open water features (ponds, channels, ditches). Upland habitats dominated by woody trees and shrubs were readily identified on the infrared aerial images and did not require groundtruthing.

Following spectral classification through the Maximum Likelihood classification algorithm and conversion to a vector map layer format, the predominant vegetation types were then merged into their broader tidal wetland categories, i.e., High Marsh, Intertidal Marsh, Fresh Marsh and *Phragmites australis*. It is important to note that prior to merging the vegetation types into the wetland classes, manual corrections were conducted, where necessary, on the vegetation type boundaries via photo-interpretation of the color-infrared imagery. Manual, photo-interpreted corrections were mostly relegated to the upper marsh boundary where classification accuracy was lowest and the vegetation types were often mixed. The native herbaceous marsh areas sustained a relative high classification accuracy and required limited or no manual boundary corrections.

With noted exceptions, definitions of intertidal marsh, coastal fresh marsh, and native high marsh followed New York State Tidal Wetland Land Use Regulations (Part 661) and New York Tidal Wetland Inventory Final Report (Martin et al. 1975) mapping conventions.

Intertidal Marsh – The classification shall be consistent with the NYSDEC mapping conventions and shall consider all areas dominated by tall- or short-form *Spartina alterniflora* to be intertidal marsh.

High Marsh – The New York State Tidal Wetland Land Use Regulations (Part 661) and Martin et al (1975) classify high marshes as areas subject to flooding during spring and storm tides and typically dominated by *Spartina patens* and *Distichlis spicata*. These documents also indicate that low vigor *Spartina alterniflora* and *Limonium carolinianum* may also be present and *Juncus gerardi*, *Scirpus* sp., *Iva frutescens,* and *Baccharis halimifolia* may occur at the upper edge of the high marsh. In general, plant communities dominated by these species were classified as "Native High Marsh", with exceptions noted in the following paragraphs.

Low vigor *Spartina alterniflora* could not be differentiated from short form *Spartina alterniflora* to separate out its occurrence in a high marsh versus intertidal marsh. Therefore, all occurrences of *Spartina alterniflora* were classified by species and grouped into intertidal marsh.

Baccharis halimifolia posed some challenges for the accurate differentiation of native high marsh habitats, as this species occurs at the upper limit of the high marsh. In cases where stands of *Baccharis halimifolia* occur at the landward margin of the high marsh, the tidal wetland-upland boundary commonly occurs within the stand. These stands at the landward margin of the high marsh are classified as salt shrub communities in the Ecological Communities of New York State (Edinger et al. 2002). It was not possible to consistently differentiate the tidal wetland-upland boundary on the infrared aerial imagery where this boundary was located within *Baccharis* stands. Therefore, as guidance for the mapping effort, the TAC established the landward margin of the native high marsh to be seaward margin of such *Baccharis halimifolia* stands.

A similar mapping challenge was also encountered in brackish meadow communities where *Spartina patens* (and sometimes *D. spicata* and *J. gerardii*) is often found landward of the native high marsh (i.e. landward of the *Iva frutescens*-dominated upper margin of the high marsh) in sandy upland areas mixed with non-wetland vegetation. The TAC established that *S. patens*-dominated brackish meadows should – where identification is possible – comprise the high marsh community.

Phragmites australis – The original NYSDEC mapping conventions do not consider *Phragmites* except to note that that *Phragmites australis* often dominates "formerly-connected tidal wetlands", i.e., areas where tidal flow has been artificially restricted or eliminated by structures. In order to quantify the expansion of *Phragmites* on Long Island since 1974, the mapping approach estimated *Phragmites australis* coverage in both 1974 and 2005/2008 imagery. Due to its ability to grow in tidal wetland, freshwater wetland, and upland habitats, determination of an accurate wetland boundary for a monoculture stand of *Phragmites australis* was not possible. Further, one objective of this project was to quantify *Phragmites australis* expansion within and adjacent to tidal wetlands in the study area. Therefore, for the purposes of trends analysis, monoculture stands of *Phragmites australis* (typically high-vigor) were considered a separate classification. It is important to note, however, that low-vigor *Phragmites australis* also commonly mixes with high marsh species such as *Spartina patens*, *Distichlis spicata*, and *Iva frutescens*. Mixed *Phragmites australis*/high marsh stands were classified as high marsh for the tidal wetland delineation and trends analysis.

Coastal Fresh Marsh – The classification was consistent with the NYSDEC mapping conventions and Part 661 and considered areas dominated by the emergent plants narrow-leaved cattail (*Typha angustifolia*) and bulrush (*Schoenoplectus* sp.) to be coastal fresh marsh.

Formerly Connected Wetlands – No wetlands were designated as "formerly connected" as this category has no ecological meaning. Wetlands categorized as formerly connected on the 1974 maps were assessed and classified as either intertidal marsh, native high marsh, native coastal fresh marsh, or more likely, *Phragmites australis*.

Littoral Zone and Coastal Shoals, Bars and Mudflats – These habitat types were not quantified as the classification of these community types depend on the review of water depth data. Water depth cannot be discerned from aerial imagery and adequate GIS bathymetric data were not available for the entire project area; accordingly, these wetland categories were not mapped.

Other Habitats – The following habitats were readily distinguishable, either through supervised classification or manual photointerpretation: 1) Salt Pannes, 2) Ponds, 3) Creeks and 4) Mosquito Ditches. These features were mapped and grouped into a single "unvegetated" classification for the purposes of later extracting their areas from the vegetated wetlands polygons. It is recognized that New York's tidal wetlands contain a variety of unvegetated or sparsely vegetated substrates such as sand, gravel, or cobble beaches, salt pannes (which often contain various densities of plant such as *Salicornia sp*. and *Limonium carolinianum*), and mudflats located seaward of or in between vegetated marsh areas. Due to the absence or low density vegetation on these substrates, the image classification used in this study cannot differentiate between traditional salt pannes and marshes that have lost vegetation due to die-off or subsidence.

The classification system described above applied to the photointerpretation of the color-infrared images for Years 2005 (Long Island Sound and Peconic Estuaries) and Year 2008 (South Shore).

For the Year 1974 color-infrared images, only the *Phragmites australis* class and the salt pannes, ponds, creeks and mosquito ditches class were mapped. The newly mapped classes for Year 1974 were merged with the existing official 1974 Tidal Wetland classes per the methods described in Subsection "Enhancement of the 1974 Tidal Wetland Boundaries" below.

It is important to note that the supervised classification described above was verified using field "test points." Test points used for verification were different than those used to train the classification algorithm. By comparing the classification map with the test points, the project team conducted the first of two error analyses: 1) test of initial classification accuracy and 2) comparison of the relative error between the manual photointerpretation and the computer-assisted, tidal wetland image classification. See Error Analysis section below.

Digitize tidal wetland boundaries using "heads-up" digitizing techniques

This task was comprised of two subtasks: (1) visual assessment and correction of Year 2005/2008 classifications and (2) enhancement of Year 1974 tidal wetland boundaries. The first subtask, performed by wetland ecologists, entails the visual assessment and correction of tidal wetland polygons developed initially through spectral analysis and classification of Year 2005 and 2008 imagery. Where tidal wetland polygons boundaries and/or their particular classifications were visually determined to be incorrect – based on photo interpretation – the image analyst utilized "heads-up", i.e., on-screen, digitizing techniques to correct the tidal wetland polygons. This entailed the cutting (i.e., splitting) of formerly unique wetland polygons, the merging of adjacent polygons into one wetland category and/or renaming the wetland category within the GIS database.

Based on a review of groundtruthed data and its evaluation with respect to available Year 2005/8 color-infrared imagery, the following overlap or confusion among feature types occurred along with a resulting misclassification of tidal wetland polygons:

- Intersection of the *Phragmites australis* and *Spartina alterniflora* spectral reflectance ranges. The reflectance values for *Phragmites australis* encompass a wide range of values from low vigor to high vigor types. Consequently, there is a small portion of the *Phragmites australis* reflectance range which intersects with that of *Spartina alterniflora*. However, because these species dominate different zones – which are typically well separated spatially – they can be easily distinguished from each other in the color-infrared photography. In addition, the two plant species are texturally different which also aids in differentiating between them in the instances where spectral misclassification may occur.
- Shadows from trees in upland areas with spectral characteristics of water bodies. Tree shadows are present, in varying degrees, across all of the color-infrared images due to variations in sun angle throughout the time period during which images were taken. The darkness of the tree shadows will cause these pixels to be misclassified as

other dark features, in particular, water bodies. Depending upon the orientation of the marsh and its upland areas to the shoreline (i.e., with respect to compass points), the tree shadow can fall across upland habitat, *Phragmites australis* or the high marsh. As part of the "heads-up" digitizing and correction process, the tree-shadow areas were reclassified according to the habitat in which the shadows fall.

- Marsh / Upland transition zones due to vegetation gradients. An important transition zone is the gradient of plant distribution that exists at the boundary between a *Phragmites australis*-dominated high marsh and an upland community without trees. In these settings, dense growth of *Phragmites australis* may extend into the upland and mix with upland vines (such as poison ivy) and shrubs (such as bayberry, multiflora rose, or groundsel bush). These transition areas are more common on the south shore where less steep topography, sandy soils, and maritime influences result in a wider transition zone between high marsh and upland with less adjacent tree cover. As a result, mapping errors resulting from diffuse marsh/upland transition zones are more likely to occur in wetland complexes in the South Shore Estuary than the Long Island Sound. In this case, the presence of a 'significant number' or ratio of one species to another will determine the boundary. The project will classify the high marsh-upland boundary, for example, based on the presence of a specified percentage of upland species. The project team will classify an area as 'upland' if upland species covered more than 50% of the ground area.
- Mixed communities at the boundaries between community types. Consider a zone where *Spartina alterniflora* and *Spartina patens* occur in roughly equal proportions (40-60% coverage of each species).
    - Mixed communities of *Spartina alterniflora* and *Spartina patens* were not mapped separately as the image classification algorithm is capable of utilizing the spectral ranges of *Spartina alterniflora* and *Spartina patens* to define discrete boundaries between the two species. However, in addition to being found spatially adjacent within a marsh, these species are also spectrally adjacent. Groundtruth data of mixed *Spartina alterniflora* and *Spartina patens* communities were used to establish a threshold at which pixels were assigned either the value of *Spartina alterniflora* or *Spartina patens.*

Small patches of one community type can be located well within another community type. Where the small patch is less than approximately 100 square feet in area, it will be combined with the larger, surrounding community type. In contrast, the New York Tidal Wetland Inventory Final Report mapping conventions indicated that the smallest wetland category to be routinely identified and delineated within a larger wetland area was five acres, although in many instances smaller areas were mapped (Martin et al. 1975).

Small patches, less than 100 square feet approximately in area, were considered insignificant due to the landscape-scale goal of the study to quantify the magnitude of landscape-level changes in wetlands loss and changes in marsh condition and implications for estuary health and supply of estuarine ecosystem services within approximately 20,000 acres of tidal wetlands within the Long Island Sound, Peconic, and South Shore Estuaries. The results of this project, the observed trends in wetland area and composition change, are intended for use by environmental managers, conservation advocates and elected officials across a variety of regulatory agencies, environmental organizations, and governments. Identification of small spatial scale variation in marsh composition (i.e. less than 100 square feet in area), while of ecological importance due to habitat complexity, was given lower priority under this project than providing landscape-level trends on Long Island's tidal wetlands that can be used by regulatory agencies, environmental organizations, and governments.

In addition, the inclusion of patches smaller than 100 square feet would make the map, and its associated spatial database, unnecessarily large and unwieldy. An example can be a small patch of *Spartina alterniflora* within a high marsh stand. If the small patch were 'large', e.g., greater than approximately 100 square feet, it would be considered a small island and would not be merged into the surrounding community type. A patch of this threshold size or greater of *Spartina alternifora* within a high marsh is likely to indicate a small depression and would be classified as intertidal marsh.

The second digitizing subtask involved the enhancement of the 1974 tidal wetland categories to include the *Phragmites australis* and unvegetated (pannes, ponds, creeks and mosquito-ditch) categories. These new polygons were extracted from the previously digitized 1974 tidal wetland polygons via a spatial "union" operation (Figure 6). Once *Phragmites australis* and unvegetated areas were removed, the acreage of Year 1974 vegetated wetland areas was recalculated to more accurately compare trends to Year 2005/2008.

It is also noted that the enhancement of the 1974 tidal wetland polygons – which were previously digitized by the NYSDEC – were also spatially corrected to match the orthorectified 1974 color-infrared images.

Figure 6: Flax Pond (Complex #103) Tidal Wetlands in 1974
[See Page D4, Appendix I for Locator Map]

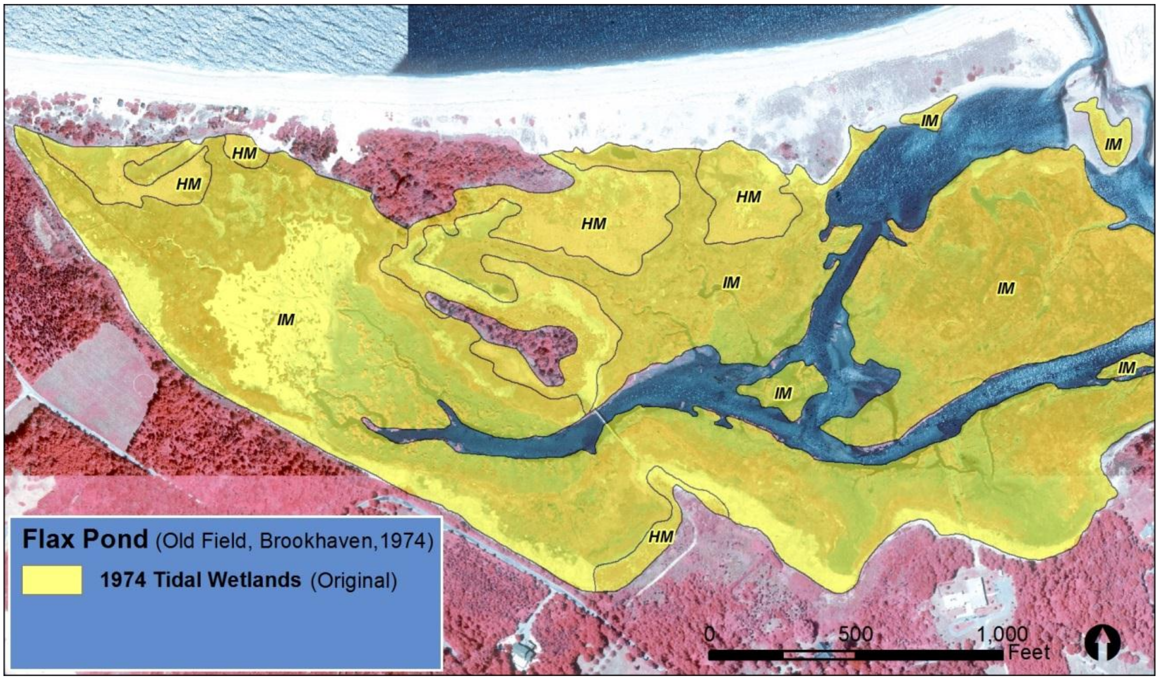
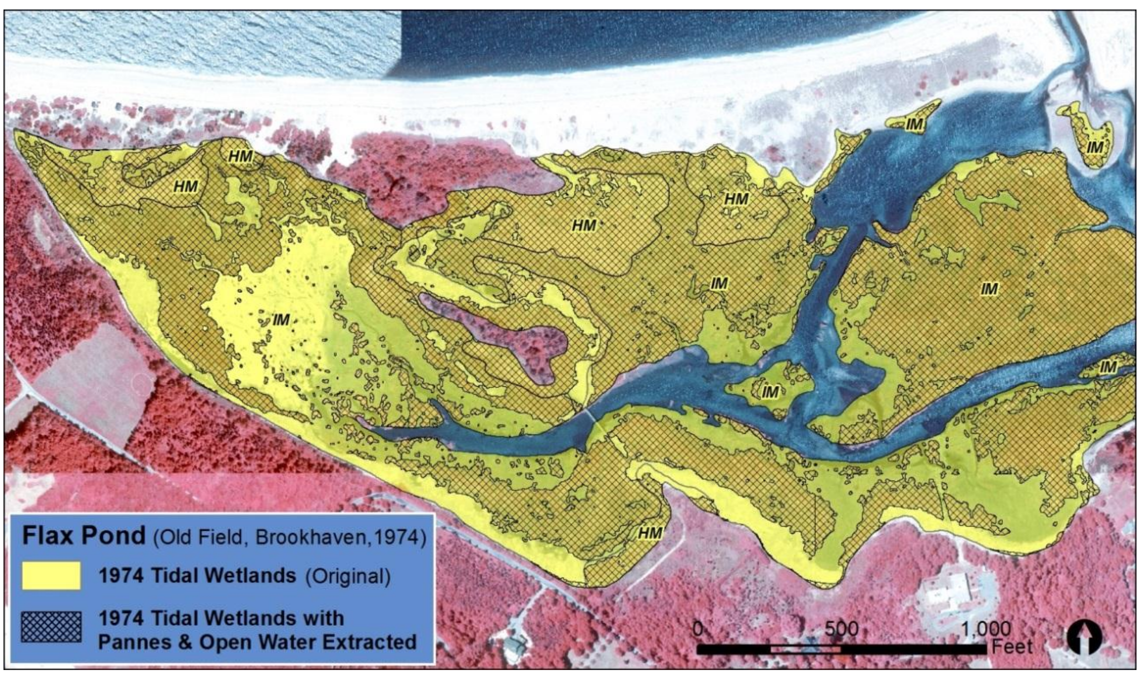


Figure 7: Flax Pond with original delineation (yellow) and enhanced delineation with unvegetated features removed (black hatch)



Trends Analysis

Total areas were calculated for intertidal marsh, high marsh, coastal fresh marsh, and *Phragmites australis* for each tidal wetland complex in 1974 and 2005/2008. The change in total vegetated tidal marsh area and total *Phragmites australis* area for each marsh complex between 1974 and 2005/2008 was calculated and tabulated as a positive or negative area and a positive or negative percentage of change.

Advantages to this method of trends analysis are that 1) a wide variety of potential changes in the tidal wetland complexes between 1974 and 2005/2008 can be captured in the calculated data such as loss of complex area or marsh type area, but also, seaward expansion of the tidal wetland, landward migration of the tidal wetland, or the formation of new tidal wetland areas since 1974 and 2) the method could be implemented over the large geographic area required for this project (more than 20,000 acres). An alternative method of trends analysis could include assessing changes in marsh or unvegetated cover type (i.e. intertidal marsh, high marsh, Phragmites, panne, mudflat, pond, creek, etc.) on the 1974 and 2005/2008 imagery at a large number of fixed, gridded points within a given marsh complex. This method of trends analysis was not feasible due to the size of the study area and large number of marsh complexes (527 complexes) and would more appropriate for implementation in a limited number of marsh priority complexes.

Based on the above data, each marsh complex was identified as "stable", i.e. less than 10% decrease or increase in marsh area between 1974 and 2005/2008, or "at-risk", i.e. more than 10% loss in marsh area. The area and percentage change data calculated for each marsh complex described above were then summed to provide trends in tidal marsh change for larger geographic areas including:

- The entire study area;
- Major estuary systems (Long Island Sound, Peconic Estuary, South Shore Estuary); and
- Long Island Towns (North Hempstead, Oyster Bay, Hempstead, Huntington, Babylon, Smithtown, Islip, Brookhaven, Riverhead, Southold, Southampton, East Hampton, and Shelter Island);

There were a number of reasons for calculating the changes in marsh features over larger geographic areas, i.e., areas larger than the scale of the marsh complex. The NEIWPCC and the broader environmental community wish to quantify marsh loss at the regional level and for major estuary systems in order to support environmental, land use and other policy initiatives. Administrative boundaries do not necessarily follow ecosystem zones or were not purposely configured to encompass critical habitats, but local officials at the County and Town levels are interested in understanding their share of responsibility for previous marsh changes and their role in future marsh protection. Agencies of the State of New York (e.g. the Department of State and the Department of Environmental Conservation), who are charged with the proper management of wetland resources, would benefit from an understanding of marsh changes within the entire study area and the three estuary systems.

To calculate 1974 to 2005/2008 tidal wetland trends for the larger geographic areas listed above, the changes in area for each marsh feature within the specified geographic area are simply summed, or tallied, based on which marsh complexes (or portions thereof) fall within the larger geographic area. Although the larger geographic areas may or may not have a specific ecological significance, the determination of marsh loss (change) trends at different geographic scales provide important information for policy makers, elected officials and environmental managers.

Results and Discussion

Long Island Tidal Wetlands Trends

Long Island's estuaries have lost 13.1 % of native intertidal (IM), high marsh (HM), and coastal fresh marsh (FM) communities between 1974 and 2005/2008 (Table 3). Appendix II provides the results of the imagery analysis and trends in marsh area for each of the identified tidal wetland complexes. The Peconic Estuary and South Shore Estuaries have slightly lower percentages of marsh loss (-10.5% and -11.6%, respectively) compared to the Long Island Sound Estuary (-22.6%). Collectively, Long Island's three estuary complexes lost, on average, 85 acres of native marsh annually over this time. These results are consistent with previous studies documenting marsh loss on Long Island (Hartig et al, 2002; Mushacke, 2007; Ciapetta, 2010; Browne, 2011) and the regional loss of salt marsh observed throughout the northeastern United States. For example, substantial marsh loss in the late 20^{th} century has similarly been reported in Connecticut (31-86% loss between 1974-2004; Tiner et al, 2006) Cape Cod (up to 50-63% between 1952/1971-2005; Smith, 2009), and Chesapeake Bay (16-29% between 1850-1990; Wray et al, 1995). These previous studies also suggest that marsh loss was likely occurring on Long Island prior to 1974, and throughout the latter half of the 20^{th} century.

The loss of nearly 3,000 acres of native wetlands implies a substantial loss of ecosystem services in Long Island's estuaries. Salt marshes provide many critical benefits to human communities including fish and shellfish production, protection of shorelines from coastal storms, erosion control and sediment stabilization, water filtration through nutrient and sediment removal, carbon sequestration, and recreation and tourism (Barbier et al, 2011). Many inter-related factors contribute to marsh loss in the northeastern United States including sea level rise; eutrophication (Deegan et al, 2012) and nutrient loading from runoff, surface water, and groundwater sources; low sediment supply; altered estuary bathymetry and inlet morphology; creek and panne expansion; expansion of invasive *Phragmites australis*; erosion caused by recreational and commercial vessel wakes; altered precipitation regimes (Watson et al. 2014); and trophic cascades resulting from interactions between marsh herbivores and their predators (Silliman et al, 2005).

Long Island's wetland complexes exhibit tremendous variability in their stability since 1974 with observed rates of change in area varying between +210.9 and -100.0% (for marshes greater than 1 acre in 1974). This variability results from 1) the multiple mechanisms contributing to marsh loss, 2) variation in the initial size and community composition of each marsh, and 3) variation in physical, biological, and anthropogenic conditions among Long Island's marshes. Smaller wetland complexes are more likely to have large magnitude changes in marsh area (either gains or losses) than large complexes. For example, all marshes showing absolute changes in area (including *Phragmites australis*) greater than 50% (i.e. more than 50% gain or more than 50% loss) were observed in marshes less than 30 acres in 1974 area. Larger variability in the stability of smaller marshes is not surprising considering that these marshes are likely to change greatly in response to localized conditions that increase or decrease the survivorship of native marsh vegetation or the erosion or accumulation of sediments.

Table 3: Tidal Wetland Area Change (1974-2005/2008) in Long Island's Estuaries

Estuary	**1974 IM + HM + FM Area (acres)**	**2005/2008 IM + HM + FM (acres)**	**Change in IM + HM + FM (acres)**	**Change in IM + HM + FM (%)**
Long Island Sound	2,891.8	2,237.6	-654.2	-22.6
Peconic Estuary	3,443.9	3,077.5	-356.4	-10.4
South Shore Estuary: Total	14,651.8	12,959.4	-1,692.3	-11.6
South Shore Estuary: East Rockaway Inlet to Fire Island Inlet	10,407.2	9,027.6.0	-1,379.6	-13.3
South Shore Estuary: Fire Island Inlet to Smith Point	2,193.7	1,885.3	-308.3	-14.1
South Shore Estuary: Moriches and Shinnecock Bays	1,956.2	2,017.1	60.9	+3.1
South Fork Ponds: Mecox Bay, Sagaponack Pond, & Georgica Pond	62.7	7.3	-55.4	-88.4
TOTAL	21,050.2	18,281.8	-2,758.3	-13.1

In addition to large reductions in total marsh area, the biological composition and geophysical structure of Long Island's tidal wetlands has also changed greatly between 1974 and 2005/2008. While this study provides analysis of trends in Long Island's marsh area only between 1974 and 2005/2008, it is important to note that previous studies on marsh loss on Long Island and the northeastern United States (Wray et al, 1995; Hartig et al, 2002; Tiner et al, 2006; Smith, 2009; Ciapetta, 2010; Browne, 2011) indicate that marsh loss was likely occurring on Long Island prior to 1974, and throughout the latter half of the 20th century. The major changes in the biological and physical structure of Long Island's marshes observed in this study are described in the following sections and include:

- Conversion of High Marsh to Intertidal Marsh
- Formation of Pannes and Ponds Within Marshes
- Conversion of Intertidal Marsh Islands to Mudflats
- Widening of Tidal Creeks and Man-made Ditches
- Erosion and Retreat of Seaward Edge
- *Phragmites australis* Encroachment

Conversion of High Marsh to Intertidal Marsh and Panne/Pond Formation

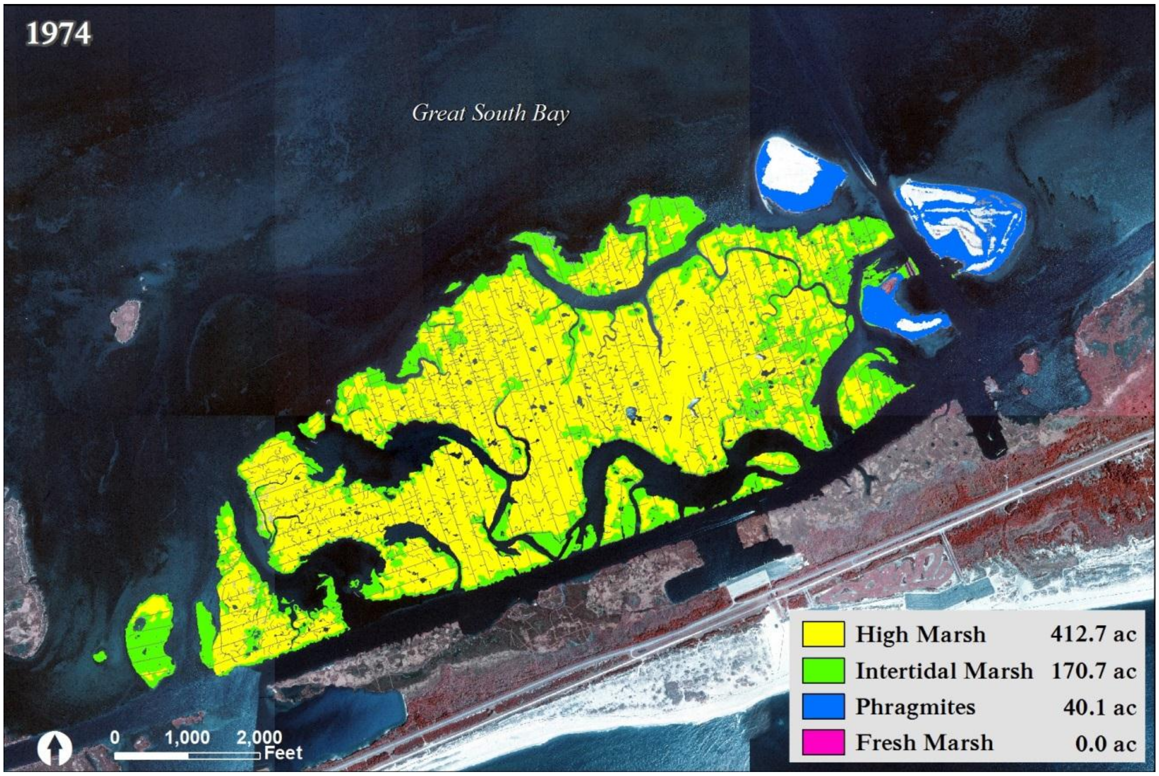
Both the conversion of high marsh to intertidal marsh and the formation of expansive panne and pond areas within marshes are indicators of marsh drowning or waterlogging. Marsh drowning may be due to the interacting effects of the failure of marsh accretional processes (such as deposition of organic sediments and accumulation of plant biomass) to keep pace with relative sea level rise and marsh subsidence related to plant mortality and subsequent decomposition of root biomass (Fagherazzi et al, 2012; Kirwan and Megonigal, 2013). This failure is due to physiological stresses such as increased flooding, sulfide accumulation, and nutrient (specifically nitrogen) loading (Turner et al, 2009; Wigand et al, 2014).

Marsh drowning has resulted in extensive conversion of native high marsh habitats to either intertidal marshes or pannes. Marshes in the Long Island Sound, Peconic, and South Shore estuaries exhibit indicators of marsh drowning with a general trend towards panne formation in the western end of the Long Island Sound and South Shore estuaries and high marsh to intertidal marsh conversion in the eastern end of the Long Island Sound and South Shore estuaries and the Peconic Estuary.

While overall rates of marsh loss over the study period range from -10.4 to -22.6%, loss of high marshes is occurring at a more rapid pace. As shown in Table 4, loss of native high marsh habitats range from -17.3 to -29.7% in the major estuary systems with a total loss of -27.1% (2,084.3 acres) of high marsh habitats. In many wetland complexes, the loss of high marsh is substantially greater than the estuary-wide totals. For example, the fifteen marsh complexes with greatest reduction in acreage of high marsh (shown in Table 5) lost -20.2 to -89.2 percent of the high marsh areas present in 1974. The cumulative area of high marsh lost in these fifteen complexes (1,467.4 acres) accounts for approximately 68% of the Long Island's high marsh losses. High marsh can transition to intertidal marsh as observed at Cedar & Nezeras Islands (Complex ID # 401, Figure 8) or pannes and ponds at Timber Point (ID # 431, Figure 9).

Due to the reduced frequency and duration of flooding, high marsh habitats exhibit both greater plant diversity and are utilized by several avian species for nesting. Approximately thirty New York State endangered, threatened, or rare plant species are endemic to high marsh habitats (New York Natural Heritage Program, 2013). Several species of birds are high marsh-nesters, such as marsh wren, salt marsh sharp-tailed sparrow, American black duck, clapper rail, willet, and black-crowned night heron. In addition, a wide variety of wading birds, waterfowl, swallows, and terns forage in and above high marsh habitats. The disproportionate loss of high marsh habitats through conversion to intertidal marsh or panne indicates that Long Island's marshes are becoming less suitable for these protected or declining species.

Figure 8: Cedar & Nezeras Islands (Complex ID #401)
[See Page F3, Appendix I for Locator Map]



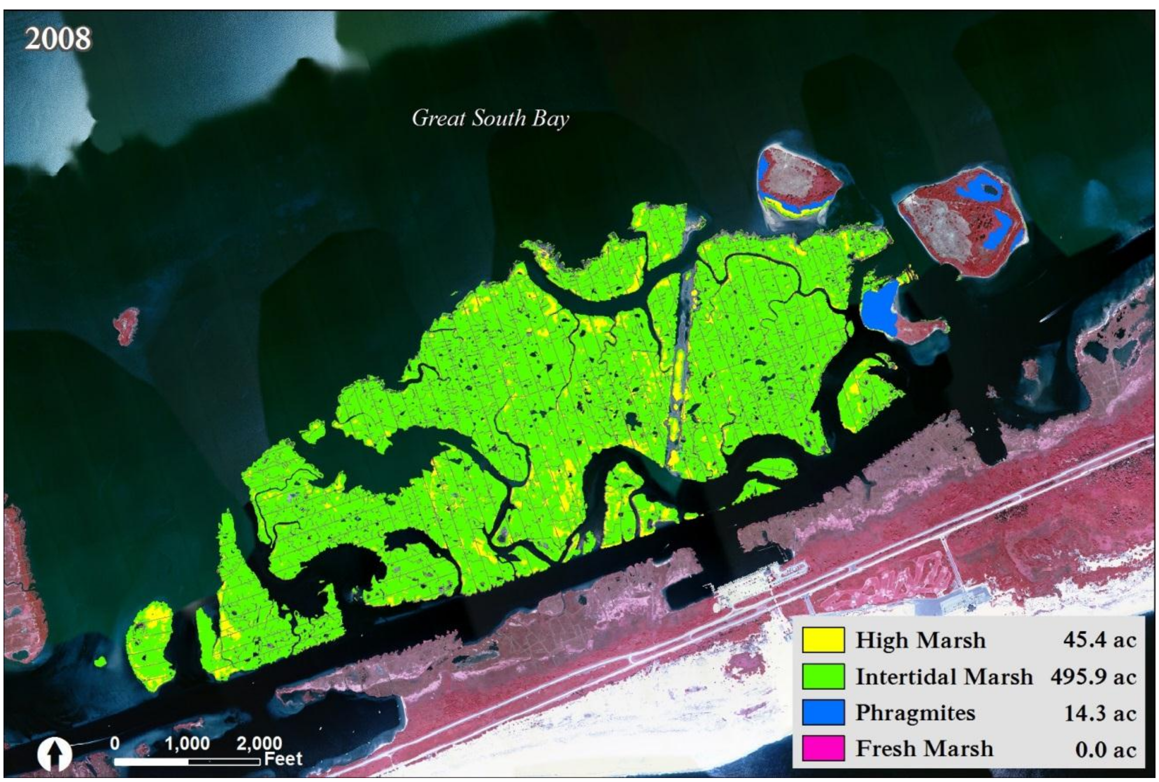
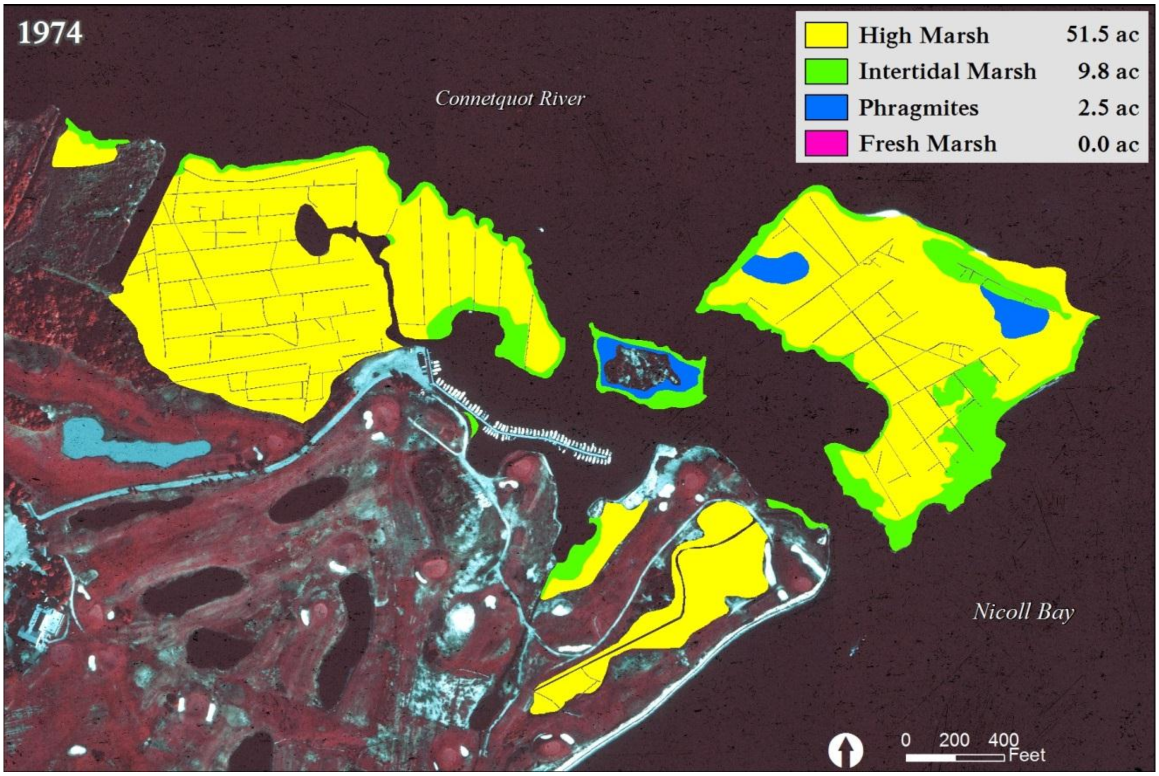
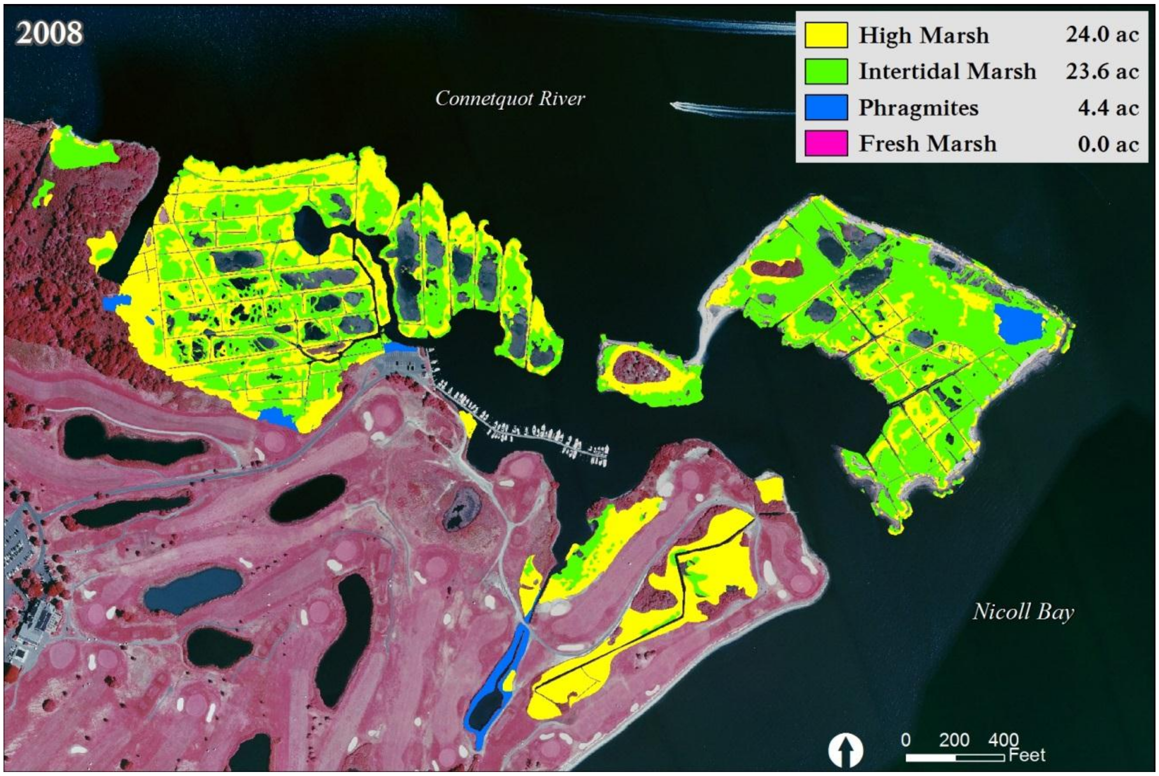


Figure 9: Timber Point (Complex ID #431)
[See Page F4, Appendix I for Locator Map]





In this study, *Iva frutescens* stands are included in the areas mapped as high marsh as are mixed stands of *Iva frutescens* and low vigor *Phragmites australis* (i.e. shoots less than approximately 6 feet in height) and low vigor *Phragmites australis* stands due to the difficulty in differentiating these cover types. Qualitative review of the mapped marshes suggests that *Iva frutescens* and *Iva frutescens/Phragmites australis* stands have increased in abundance between 1974 and 2005/2008. Increases in *Iva frutescens* and *Iva frutescens/Phragmites australis* stand area in high marshes (particularly landward expansion of these stands) could partially offset losses in native herbaceous high marsh dominated by *Spartina patens*, *Distichlis spicata*, and *Juncus gerardii*. Accordingly, it is likely that the native herbaceous high marshes have experienced greater losses than the high marsh loss trends presented in Table 4.

The approximately 30% loss of high marsh habitats throughout Long Island between 1974 and the mid 2000's and resulting loss of ecosystem services and habitat for wildlife and rare plants demands restoration efforts in complexes with greatest losses of high marsh area (Table 5) and increased management in the largest remaining high marshes (Table 6). Appendix II provides complete marsh area data for 1974 and 2005/2008 imagery for all marsh cover types and marsh change data for each of the identified marsh complexes.

Table 4: High Marsh Area Change (1974-2005/2008) in Long Island's Estuaries

Estuary	1974 HM Area (acres)	2005/2008 HM Area (acres)	Change (acres)	Change (%)
Long Island Sound	950.2	785.9	-164.3	-17.3
Peconic Estuary	1,862.0	1,393.8	-468.2	-25.1
South Shore Estuary	4,856.8	3,414.8	-1,442.0	-29.7
East Rockaway to Fire Island Inlet	2,306.1	1,526.8	-779.3	-33.8
Fire Inlet to Smith Point	1,547.7	998.3	-549.4	-35.5
Moriches and Shinnecock Bay	1,003.0	889.7	-113.3	-11.3
South Fork Ponds	13.6	3.8	-9.8	-71.8
Long Island Total	7,682.6	5,598.3	-2,084.3	-27.1

Table 5: Wetland Complexes with Greatest High Marsh Area Change (1974-2005/2008)

Complex (ID#)	1974 High Marsh (acres)	2005 High Marsh (acres)	Δ High Marsh (acres)	Δ High Marsh (%)
Cedar & Nezeras Islands (401)	412.71	45.44	-367.28	-89.0
Captree Island & Seaganus Thatch (410)	276.85	96.61	-180.2	-65.1
Fireplace Neck & Carmans River West (461)	231.54	104.47	-127.06	-54.9
Fire Island National Seashore (445)	357.72	241.40	-116.33	-32.5
Crab Meadow (222)	157.92	60.69	-97.23	-61.60
Accabonac Harbor (156)	179.24	90.61	-88.63	-49.45
Smith Point County Park East (478)	241.16	168.90	-72.26	-30.0
Marsh Islands North of State Boat Channel (386)	73.90	18.79	-55.1	-74.6
Northwest Creek (165)	106.71	52.02	-54.69	-51.25
Carmans River East (462)	166.30	118.36	-47.94	-28.8
Napeague Meadows (154)	231.79	185.06	-46.73	-20.16
South Line Island (382)	66.32	22.80	-44.51	-65.6
Dune Road Marsh & Islands West (516)	149.62	107.37	-42.25	-28.2
Gilgo & Great Islands (394)	120.77	77.81	-42.96	-35.6
Wading River Marsh (87)	105.74	65.24	-40.49	-38.34

Table 6: Wetland Complexes with Largest High Marsh Areas in 2005/2008

Complex (ID #)	2005/2008 High Marsh (acres)
Fire Island National Seashore (445)	241.4
Napeague Meadows (154)	185.1
Smith Point County Park East (478)	168.9
Carmans River East (462)	118.4
Fireplace Neck & Carmans River West (461)	104.5
Dune Road Marsh & Islands West (516)	107.8
Tobay Sanctuary West (385)	97.6
Captree Island & Seaganus Thatch (410)	96.6
Hubbard Creek (14)	94.8

Complex (ID #)	2005/2008 High Marsh (acres)
Accabonac Harbor (156)	90.6
Gilgo & Great Islands (394)	77.8
Lawrence Marsh (322)	76.9
Quintuck Creek (429)	69.4
North & South Green Sedge Islands (325)	67.7
Wading River Marsh (87)	65.2

Many wetland complexes with large losses of high marsh habitats through marsh drowning and subsidence exhibit large gains in intertidal marsh as shown in Table 7, which presents the marsh area change for each of the complexes identified in Table 5, and Table 8, which presents the marsh complexes with the largest observed gains in intertidal marsh area. In contrast, other marsh complexes with large losses of high marsh habitats exhibited large reductions in total marsh area and due to the conversion of high marsh to pannes, marsh ponds, and open water, as shown at Timber Point (ID # 431, Figure 9). Wetland complexes showing significant losses in intertidal marsh, either in acreage or percent loss, are predominantly located in the western South Shore estuary (acreage) or Long Island Sound (percent loss) (Table 9 and Table 10, respectively). Considered in conjunction with the observed losses of high marsh, the observed trends in intertidal marshes indicate that substantial subsidence/drowning of tidal marshes is occurring throughout Long Island's three major estuary systems.

Table 7: Intertidal Marsh Change for Wetland Complexes with Greatest High Marsh Area Change (1974-2005/2008)

Complex	1974 Intertidal Marsh (acres)	2005 Intertidal Marsh (acres)	Δ Intertidal Marsh (acres)	Δ Intertidal Marsh (%)
Cedar & Nezeras Islands (401)	170.7	495.9	325.2	190.5
Captree Island & Seaganus Thatch (410)	315.6	441.0	123.4	38.9
Fireplace Neck & Carmans River West (461)	8.9	115.3	106.4	1200.3
Fire Island National Seashore (445)	123.9	218.0	94.1	75.9
Crab Meadow (222)	84.1	147.6	63.5	75.5
Accabonac Harbor (156)	42.2	123.7	81.4	192.8
Smith Point County Park East (478)	71.9	136.2	64.3	89.4
Marsh Islands North of State Boat Channel (386)	534.0	485.8	-48.2	-9.0
Northwest Creek (165)	41.9	85.2	43.3	103.3
Carmans River East (462)	25.9	47.0	21.2	81.8
Napeague Meadows (154)	5.2	48.0	42.8	823.8
South Line Island (382)	296.1	289.5	-6.7	-2.3
Dune Road Marsh & Islands West (516)	222.0	266.9	44.9	20.2
Gilgo & Great Islands (394)	140.2	176.9	36.7	26.2
Wading River Marsh (87)	31.8	61.1	29.3	92.2

Table 8: Wetland Complexes with Greatest Intertidal Marsh Area Gain 1974-2005/2008

Complex (ID #)	1974 IM Area (acres)	2005 IM Area (acres)	Δ IM (acres)	Δ IM (%)
Cedar & Nezeras Islands (401)	170.7	495.9	325.2	190.5
Captree Island & Seaganus Thatch (410)	317.6	441.0	123.4	38.9
Fireplace Neck & Carmans River West (461)	8.9	115.3	106.4	1200.3
Fire Island National Seashore (445)	123.9	218.0	94.1	75.9
Accabonac Harbor (156)	42.2	123.7	81.4	192.8
Smith Point County Park East (478)	71.0	136.2	64.3	89.4
Crab Meadow (222)	84.08	147.58	63.50	75.5
Tobay Sanctuary West (385)	25.7	79.8	54.1	210.8
Dune Road Marsh & Islands West (516)	222.0	266.9	44.9	19.80
Northwest Creek (165)	41.9	85.2	43.3	103.3
Napeague Meadows (154)	5.2	48.0	42.8	823.8
Gilgo & Great Islands (394)	140.2	176.9	36.7	26.2
Wading River Marsh (87)	31.8	61.1	29.3	92.2
Browns Point to Peters Neck Point (32)	11.9	40.1	28.2	237.5
Elder Island (397)	35.0	60.5	25.6	73.1

Table 9: Wetland Complexes with Greatest Intertidal Marsh Area Loss

Complex (ID #, Town)	1974 IM Area (acres)	2005 IM Area (acres)	Δ IM (acres)	Δ IM (%)
Lawrence Marsh (322, Hempstead)	540.1	461.6	-78.5	-14.5
North & South Green Sedge Islands (325, Hempstead)	279.1	205.4	-73.8	-26.4
Porpoise Channel Islands (105, Smithtown)	106.7	48.5	-58.2	-54.6
Cuba, Middle & East Islands (367, Hempstead)	222.0	170.0	-49.7	-22.6
Jones, Middle & West Cow Islands (364, Hempstead)	317.6	272.3	-45.3	-14.3
Marsh Isl. North of State Boat Channel (386, Oyster Bay)	534.0	485.8	-48.2	-9.0
Pine Marsh (356, Hempstead)	189.8	146.6	-43.2	-22.8
Cinder & North Cinder Islands (344, Hempstead)	120.1	77.3	-42.8	-35.6
East Channel Islands (341, Hempstead)	116.2	73.6	-42.6	-36.7
Garrett Marsh (339, Hempstead)	162.9	120.3	-42.6	-26.1
High Meadow Island (352, Hempstead)	158.7	117.1	-41.6	-26.2
Seadog Island (351, Hempstead)	136.2	96.6	-39.6	-29.1
Smith Meadow Island (353, Hempstead)	172.4	132.6	-39.8	-23.1
Hutchinson River (550, Bronx)	63.7	25.0	-38.7	-60.8
Alder Island/Loop Parkway (350, Hempstead)	173.3	135.2	-38.1	-22.0

Table 10: Wetland Complexes with Greatest Intertidal Marsh Area Loss (Percent)

Complex (ID #, Town)	1974 IM Area (acres)	2005 IM Area (acres)	Δ IM (acres)	Δ IM (%)
Ponquogue Islands (528, Southampton)	11.0	1.0	10.0	-90.7
Sheets Creek (275, North Hempstead)	9.8	1.0	8.8	-89.9
Northport Harbor Bird Island (225, Huntington)	16.8	2.5	14.3	-85.0
Northport Harbor (226, Huntington)	19.3	4.4	15.0	-77.4
LI Sound- Milton Point to Rye Beach (314, Rye)	9.8	2.7	7.1	-72.1
West Pond (261, Oyster Bay)	20.1	7.5	12.6	-62.6
Mitchell Creek (282, North Hempstead)	11.8	4.6	7.2	-61.1
Hutchinson River (550, Bronx)	63.7	25.0	38.7	-60.8
Huntington Harbor (233, Huntington)	18.8	7.6	11.3	-59.9
Cold Spring Harbor East (240, Huntington)	11.1	4.5	6.6	-59.7
Cold Spring Harbor Inner Harbor (241, Huntington)	12.4	5.5	6.9	-55.7
Porpoise Channel (105, Smithtown)	106.7	48.5	58.2	-54.6
West Meadow Island (334, Hempstead)	19.2	9.2	10.1	-52.3
Macy Channel & Georges Island (327, Hempstead)	32.5	16.2	16.2	-50.0

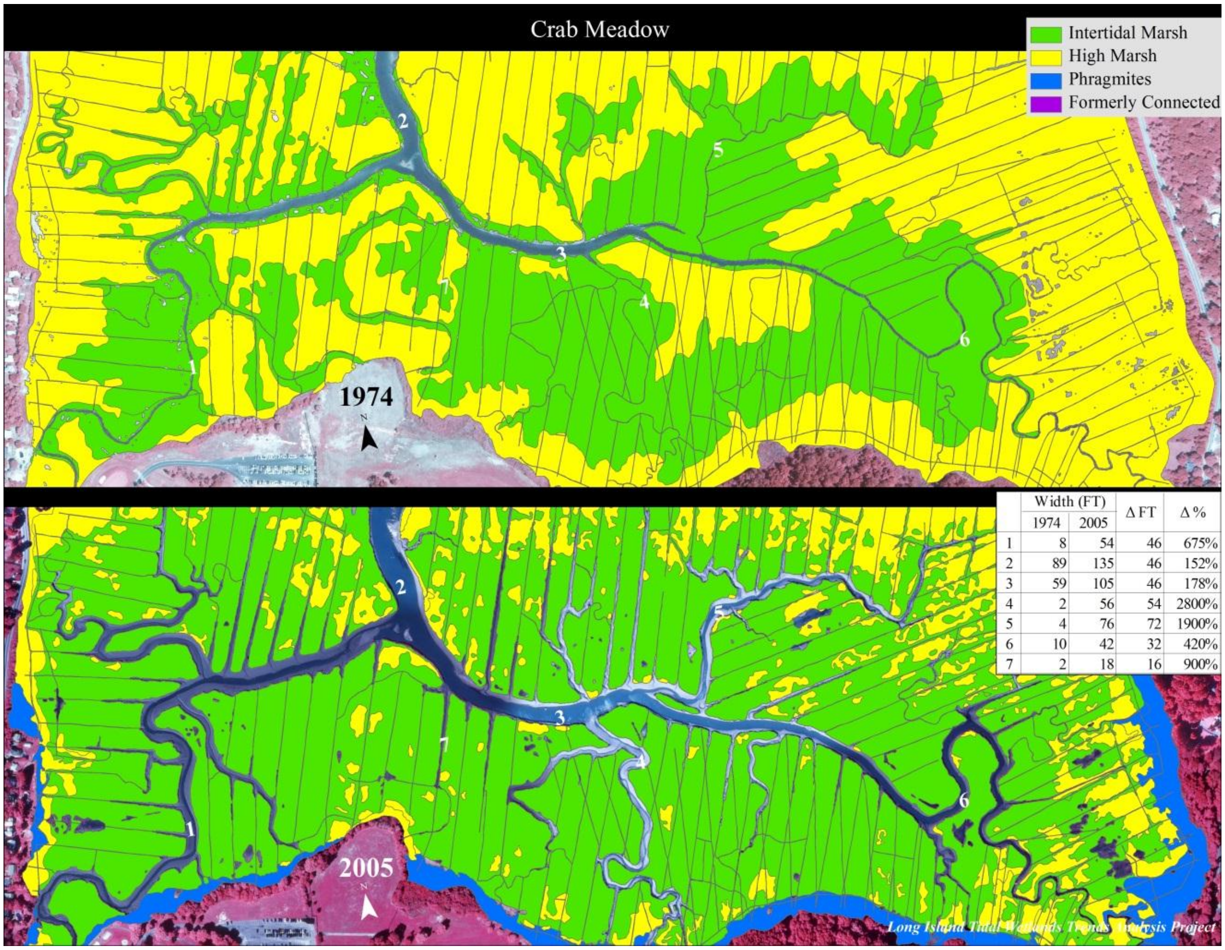
Widening of Tidal Creeks and Man-made Ditches

Comparison of the 1974 and 2005/2008 aerial imagery indicates widening of natural tidal creeks and man-made ditches in many Long Island marsh complexes. Creek widening in other degrading marshes in the northeastern United States has been attributed to reduced structural integrity and collapse of creek banks resulting from reduced root biomass, increased decomposition of organic matter, and increased soil water content (Deegan et al, 2012) and, in some cases, herbivory from *Sesarma* crabs (Smith, 2009). Creek width and cross-sectional area is related to the geomorphological and hydrological characteristics of the marsh and surrounding estuary and, as a result, may be impacted by changes in tidal prism (Vandenbruwaene et al, 2013) resulting from relative sea level rise (Stefanon et al, 2012) or anthropogenic changes in inlet or estuary bathymetry. Creek banks, particularly in large tidal channels, may also be subject to erosional forces from wind-driven waves during storms, greater water flow rates, and vessel wakes. At Crab Meadow Marsh (ID# 222) creek and ditch width increased by 1-72 feet (152 – 2,800%) at seven locations within the tidal creek network (Figure 10). At Pine Marsh (ID # 356), creek and ditch width increased by 12-20 feet (192 – 525%) at seven locations within the marsh (Figure 11).

Erosion and Retreat of Seaward Edge

Many marshes in Long Island's estuaries exhibit pronounced retreat of the seaward marsh edge. The recession of marsh edges is influenced by similar processes to bank collapse and widening.

Figure 10: Crab Meadow (Complex ID #222) - Expansion & Widening of Tidal Creeks & Man-Made Ditches
[See Page D3, Appendix I for Locator Map]

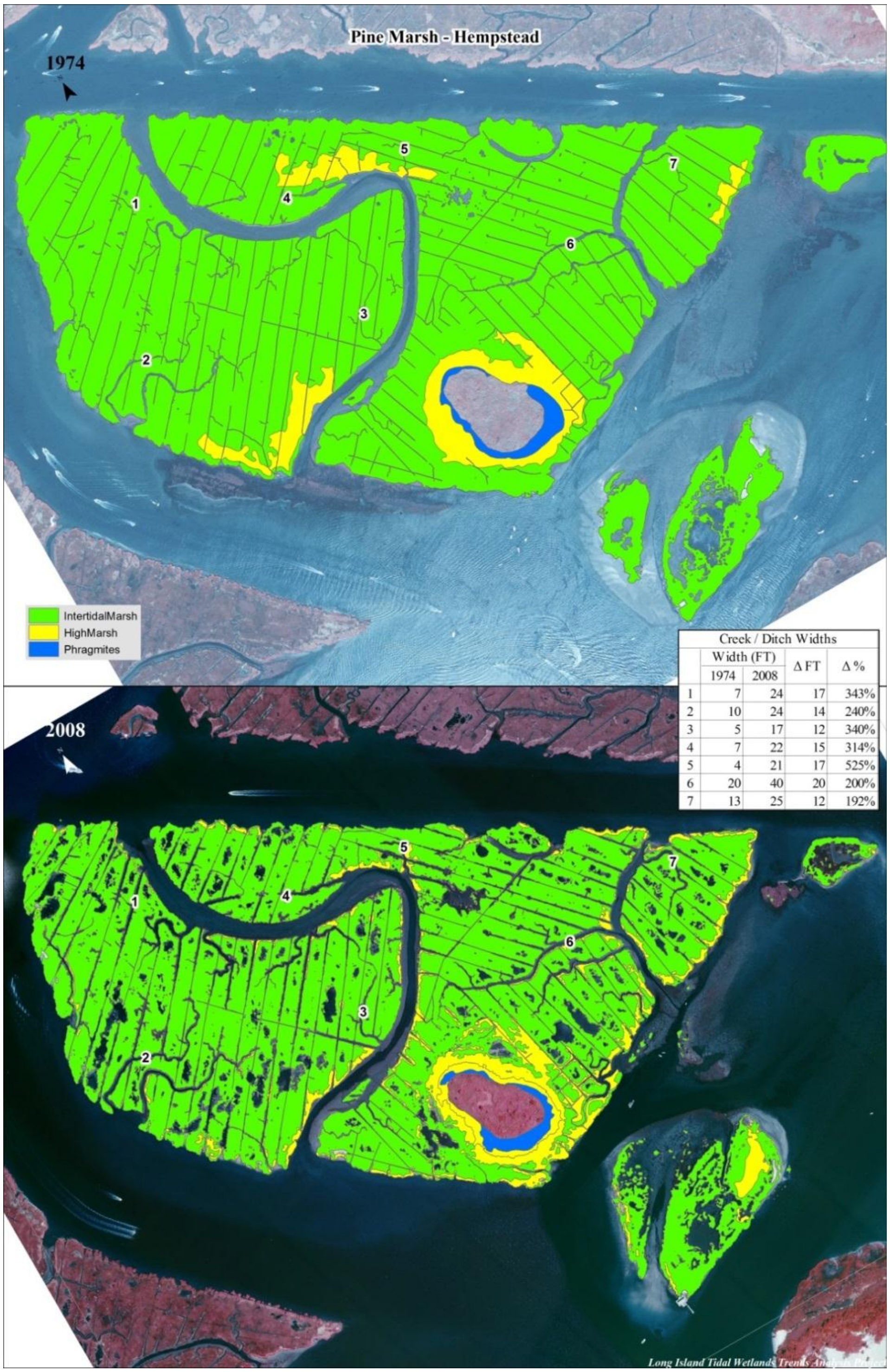


However, due to their less sheltered position, marsh edges are subjected to greater erosional forces from vessel wakes and during storms. Browne (2011) determined that the marsh edges in Hempstead Bay receded by 17.8 m over the past 90 years. Edge recession was 3.25 times greater in navigation channels dredged through marsh islands compared to natural marsh edges (Browne, 2011). In addition, other anthropogenic disturbance of the seaward edge of the marsh such as the harvesting of ribbed mussels from the marsh or harvesting of shellfish from the subtidal mudflats adjacent to *Spartina alterniflora* may also affect the stability of the seaward edge of the marsh and *Spartina* recruitment.

Receding marsh shorelines were frequently observed in the Long Island Sound and South Shore estuaries (Figure 12-Figure 14). Indicators of eroding marsh shorelines include scalloping of marsh shorelines, thinning of marsh peninsulas, and reticulation of the marsh shoreline (Hartig et al. 2002). The seaward marsh edge of Tobay Sanctuary (ID # 385) has receded by 102 – 200 feet based on measurements at five locations (Figure 12). The seaward marsh edge of the western shoreline of Hempstead Harbor (ID # 267) has receded by an average of 34 feet based on measurements at 32 locations (Figure 13). Thinning of marsh peninsulas and scalloped marsh edges are also visible in Cuba, Middle, and East Islands (ID # 367, Figure 14).

Figure 11: Pine Marsh (Complex ID #356) – Expansion and Widening of Tidal Creeks & Man-Made Ditches

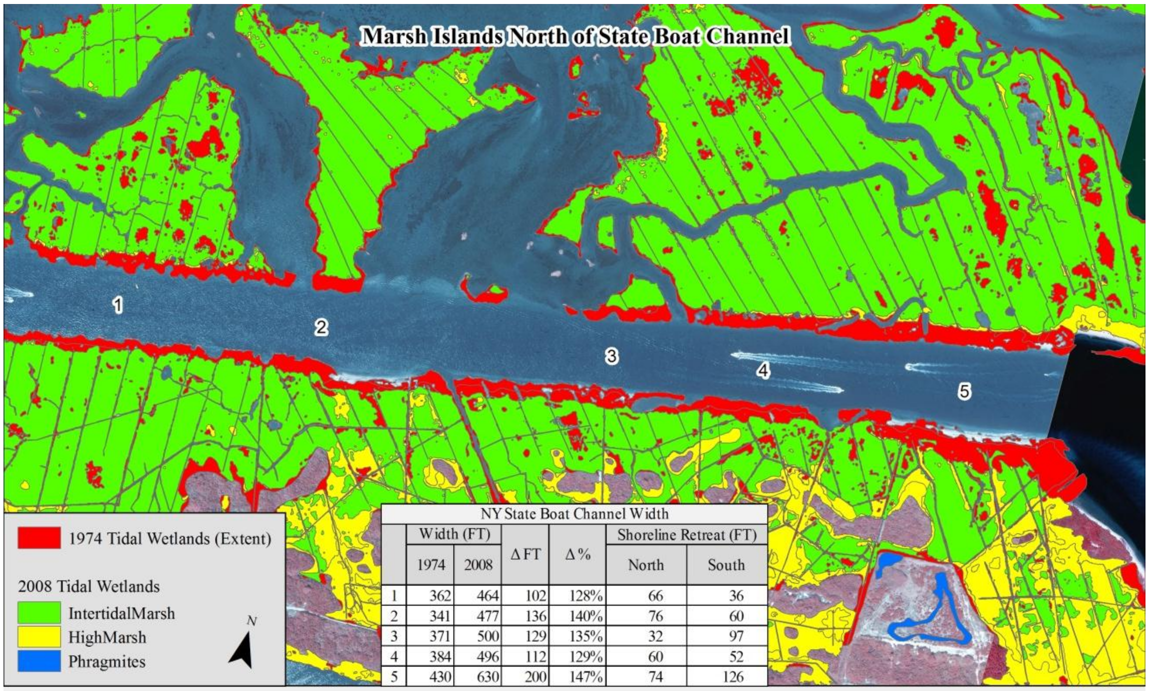
[See Page F2, Appendix I for Locator Map]



Creek / Ditch Widths				
	Width (FT)		ΔFT	Δ%
	1974	2008		
1	7	24	17	343%
2	10	24	14	240%
3	5	17	12	340%
4	7	22	15	314%
5	4	21	17	525%
6	20	40	20	200%
7	13	25	12	192%

Figure 12: Tobay Sanctuary (Complex ID # 385) / Marsh Islands North & South of State Boat Channel (Complex ID # 386) – Marsh Edge Retreat

[See Page F3, Appendix I for Locator Map]



NY State Boat Channel Width						
	Width (FT)		ΔFT	Δ%	Shoreline Retreat (FT)	
	1974	2008			North	South
1	362	464	102	128%	66	36
2	341	477	136	140%	76	60
3	371	500	129	135%	32	97
4	384	496	112	129%	60	52
5	430	630	200	147%	74	126

Figure 13: Inner Hempstead Harbor West Shoreline (Complex ID # 267) – Marsh Edge Retreat

[See Page E2, Appendix I for Locator Map]

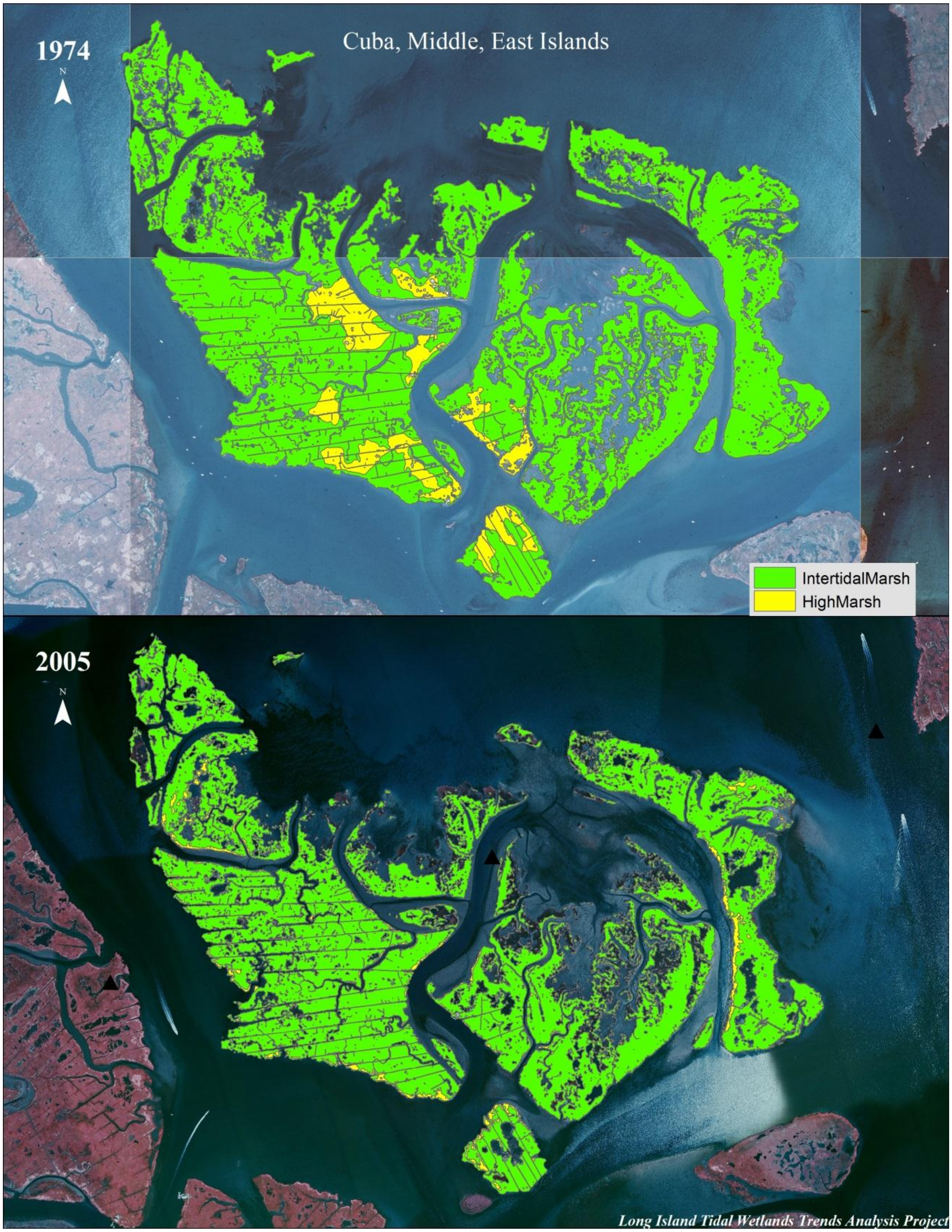
Shoreline Change Analysis

Point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Shoreline Change (FT)	-54	-40	-23	-79	-50	-20	-3	-63	0	6	21	26	-3	-136	-104	14

Point	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Shoreline Change (FT)	14	-24	-15	-30	-49	-32	-45	-21	-35	-33	-72	-121	2	-9	-11	-83

# of Points	32
Average Shoreline Change (FT)	-34
Maximum Shoreline Retreat (FT)	-136
Maximum Shoreline Accretion (FT)	26

Figure 14: Cuba, Middle, and East Islands (Complex ID # 367) – Marsh Edge Retreat
[See Page F2, Appendix I for Locator Map]



Phragmites australis Expansion

Invasive *Phragmites australis* has colonized large areas of high marsh and coastal fresh marsh habitats on Long Island. However, many of Long Island's marshes were infested by *Phragmites australis* prior to 1974 (Table 11 and Table 12). *Phragmites australis* has historically been found in slightly brackish, tidal fresh marshes, and the borders of salt and brackish marshes; but has increasingly been colonizing salt and brackish marshes (Orson, 1999; Tiner, 2009). *Phragmites australis* poses significant problems for wetlands mapping due to 1) its capability to grow in tidal wetland, freshwater wetland, and upland habitats and 2) its variable spectral signature. Accordingly, *Phragmites australis* identified in Table 11 can be growing in former high marsh habitats or adjacent freshwater wetlands or upland habitats. As such, areas identified as *Phragmites australis* are not necessarily tidal wetlands and are not included in the totals for vegetated marsh area (Table 3).

Long Island's estuaries exhibit different trends regarding *Phragmites australis* abundance (Table 12). In the Long Island Sound, Peconic Estuary, and the coastal bays in Southampton and East Hampton, *Phragmites australis* encroachment has contributed to the drastic loss of native high marsh communities and led to the near eradication of areas classified as coastal fresh marsh. Coastal fresh marsh communities consists of various bulrushes (*Schoenoplectus* spp., *Bulboschoenus* spp., and *Scirpus* spp.), narrow-leaved cattail (*Typha angustifolia*), brackish cordgrasses (*Spartina cynosuroides* and *Spartina pectinata*), and emergent plants such as arrow arum (*Peltandra virginica*) and pickerelweed (*Pontederia* spp.) (Martin et al, 1975). Native tidal marshes most susceptible to *Phragmites australis* encroachment include marshes adjacent to disturbed upland, marshes with groundwater contributions, marshes with altered hydrology, or a combination of these impacts. Proliferation of *Phragmites australis* in the headwater creeks and shorelines of Mecox Bay (ID # 540) is likely the result of clearing, disturbance, and nutrient loading in the adjacent uplands (Figure 15). The southern portion of Accabonac Harbor (ID # 156, East Hampton) has seen the loss of approximately 39 acres of coastal fresh marsh and conversion to *Phragmites australis* (Figure 16). Baiting Hollow Marsh (ID # 85, Riverhead) has lost 19.8 acres of high and intertidal marsh to *Phragmites australis* and open water as the result of the gradual shoaling and closure of the marsh's inlet to the Long Island Sound (Figure 17).

Phragmites australis has continued to colonize high and coastal fresh marshes within the South Shore Estuary. However, overall *Phragmites australis* coverage within the South Shore estuary has decreased by 11.9%. Loss of *Phragmites australis* areas is most prevalent on former dredge spoil sites located west of Fire Island Inlet and in Moriches and Shinnecock Bays. In some cases, *Phragmites australis*-dominated dredge spoil has naturally transitioned to native marsh communities on dredge spoils, presumably, to sea level rise and/or restoration of tidal hydrology as shown at Pearsalls Hassock (ID # 333, Figure 18) and Blackbank Hassock (ID # 336, Figure 19). In other cases, *Phragmites australis*- dominated dredge spoils may have transitioned to upland vegetation (perhaps due to increase in elevation resulting from repeated use of the spoil site) or bare sand (perhaps due to recent use of the spoil site).

Table 11: Phragmites Area Change (1974-2005/2008) in Long Island's Estuaries

Estuary	1974 *Phragmites* Marsh (acres)	2005/2008 *Phragmites* Marsh (acres)	Change in *Phragmites* (acres)	Change in *Phragmites* (%)
Long Island Sound	317.1	423.7	106.6	+33.6
Peconic Estuary	304.2	573.6	269.3	+88.5
South Shore Estuary: Total	1,839.0	1,620.2	-218.8	-11.9
South Shore Estuary: East Rockaway Inlet to Fire Island Inlet	582.3	370.4	-211.9	-36.4
South Shore Estuary: Fire Island Inlet to Smith Point	786.1	944.0	157.9	+20.1
South Shore Estuary: Moriches and Shinnecock Bays	470.7	305.8	-164.8	-35.0
South Fork Ponds: Mecox Bay, Sagaponack Pond, Georgica Pond	21.5	106.5	85.0	+395.7
TOTAL	2,481.8	2,724.0	242.1	+9.8

Table 12: Wetland Complexes with Greatest Increase in Phragmites Area (1974-2005/2008)

Complex (ID #, Town)	1974 *Phragmites* (acres)	2005 *Phragmites* (acres)	Δ *Phragmites* (acres)
Mecox Bay & Beach (540, Southampton)	9.7	73.2	63.5
Carmans River East (462, Brookhaven)	35.8	96.4	61.6
Accabonac Harbor (156, East Hampton)	3.0	41.4	38.5
Fireplace Neck & Carmans River West (461, Brookhaven)	26.6	60.3	33.6
Jones Beach West Tip (371, Hempstead)	0.0	25.5	25.5
Northwest Creek (165, East Hampton)	32.2	55.6	23.4
Gardiner's Island Bostwick Creek (109, East Hampton)	0.0	22.9	22.9
Wading River Marsh (87, Riverhead)	7.7	25.6	17.9
Carmans River Upstream FM (463, Brookhaven)	46.1	61.8	15.7
Alewife Brook & Pond (163, East Hampton)	1.1	16.5	15.4
Little Northwest Creek (167, East Hampton)	0.0	15.0	15.0
Pepperidge State Tidal Wetlands (434, Islip)	21.8	36.2	14.4
Indian Creek (435, Islip)	21.3	35.6	14.3
Crab Meadow (222, Huntington)	6.2	19.9	13.7

Figure 15: Mecox Bay (Complex ID #540) – *Phragmites australis* Expansion

[See Page D9, Appendix I for Locator Map]

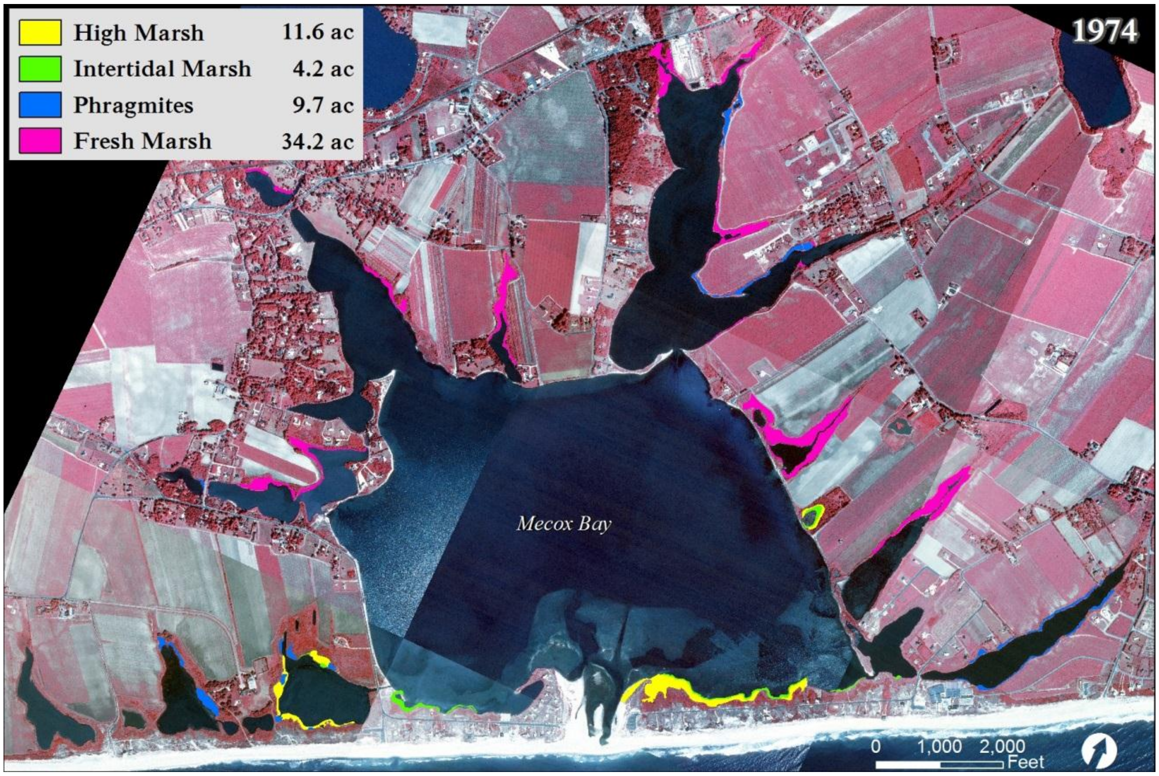
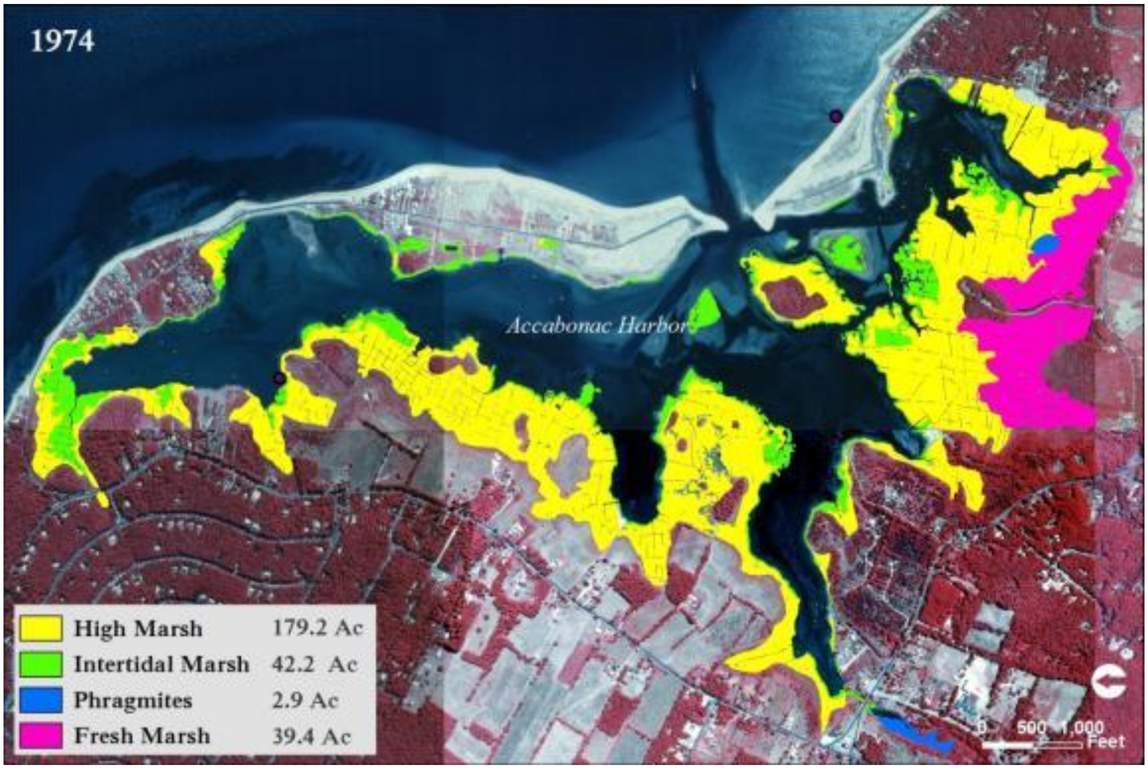


Figure 16: Accabonac Harbor (Complex ID #156) – *Phragmites australis* Expansion
[See Page C10, Appendix I for Locator Map]



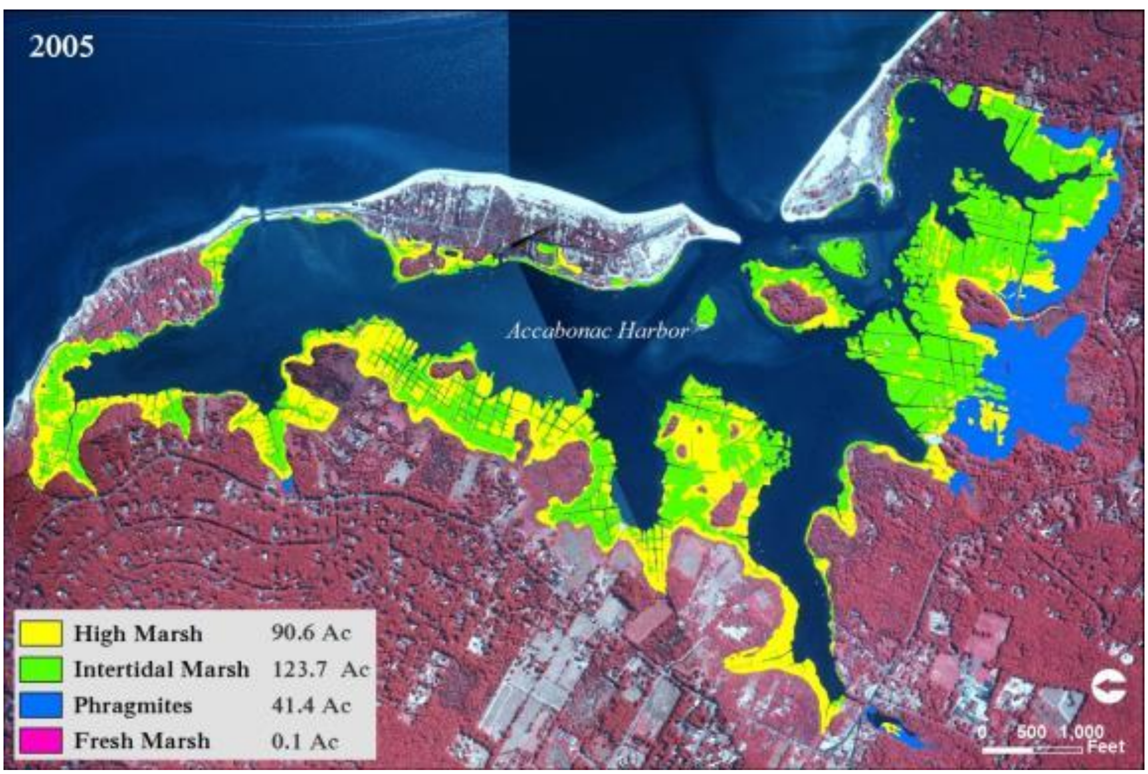
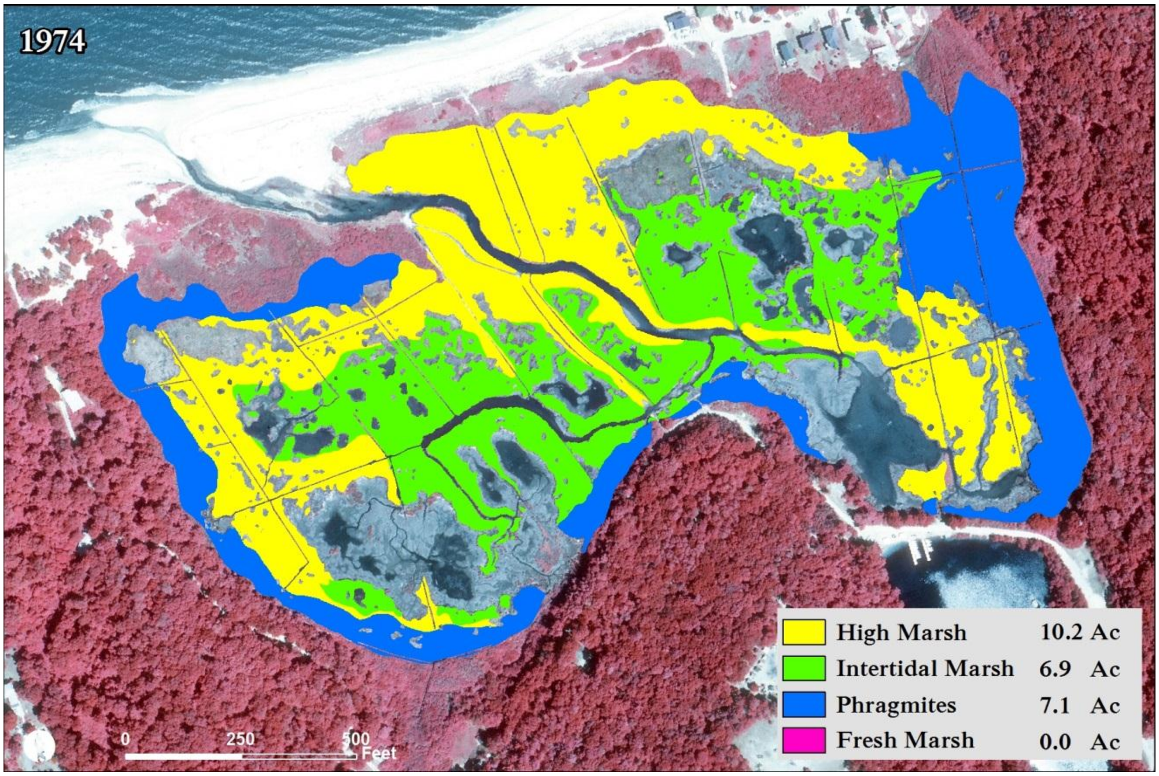


Figure 17: Baiting Hollow Marsh (Complex ID #85) – Phragmites Expansion

[See Page D6, Appendix I for Locator Map]



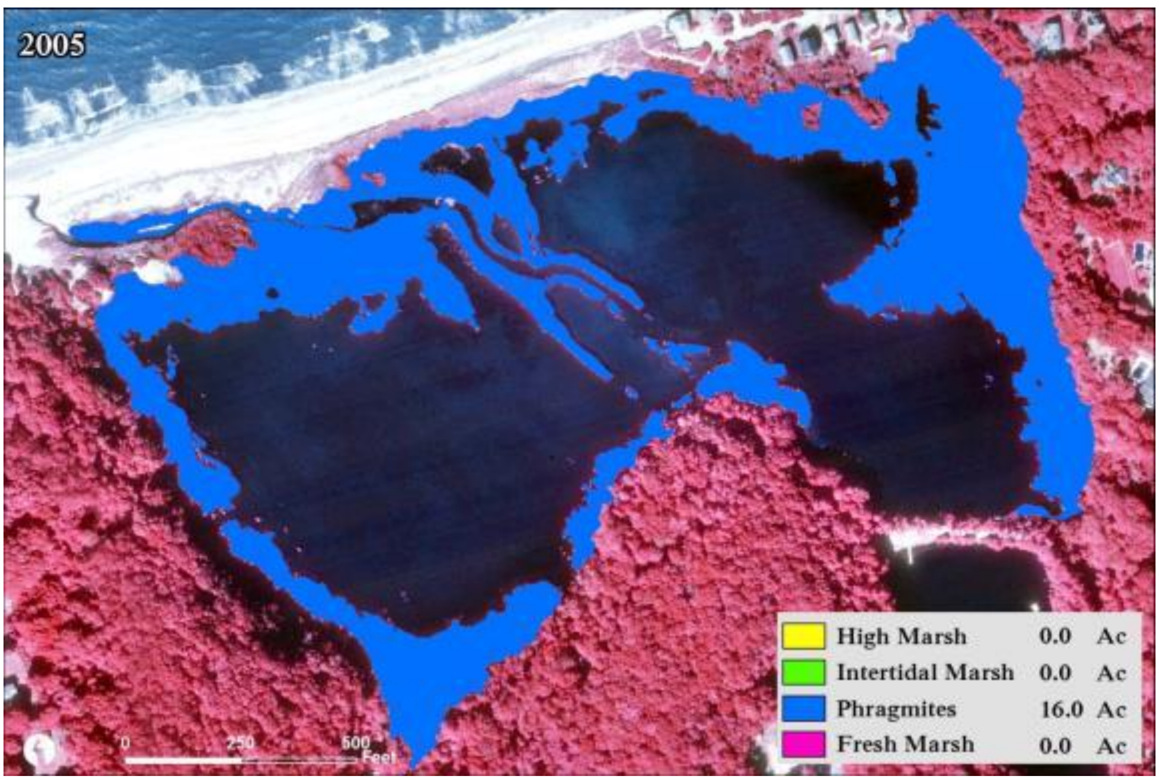


Figure 18: Pearsalls Hassock (Complex ID #333) – Conversion of former *Phragmites australis* Stands to Native Marsh and Upland

[See Page F1, Appendix I for Locator Map]

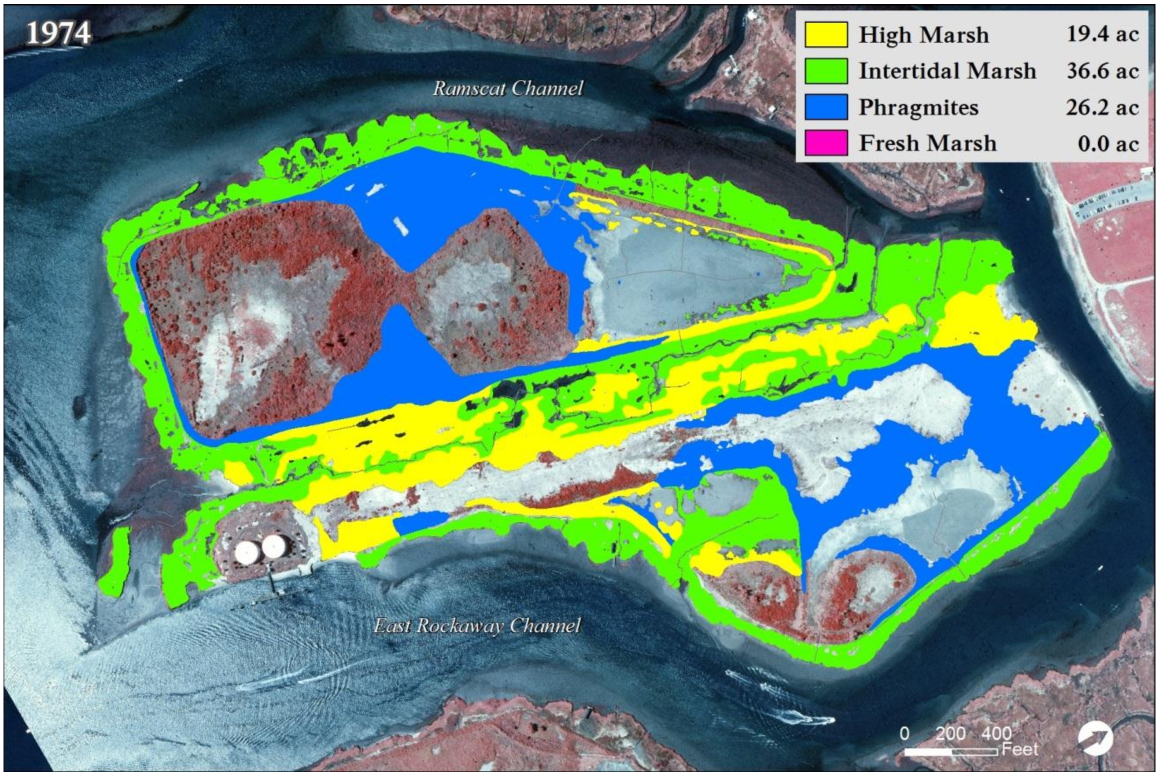
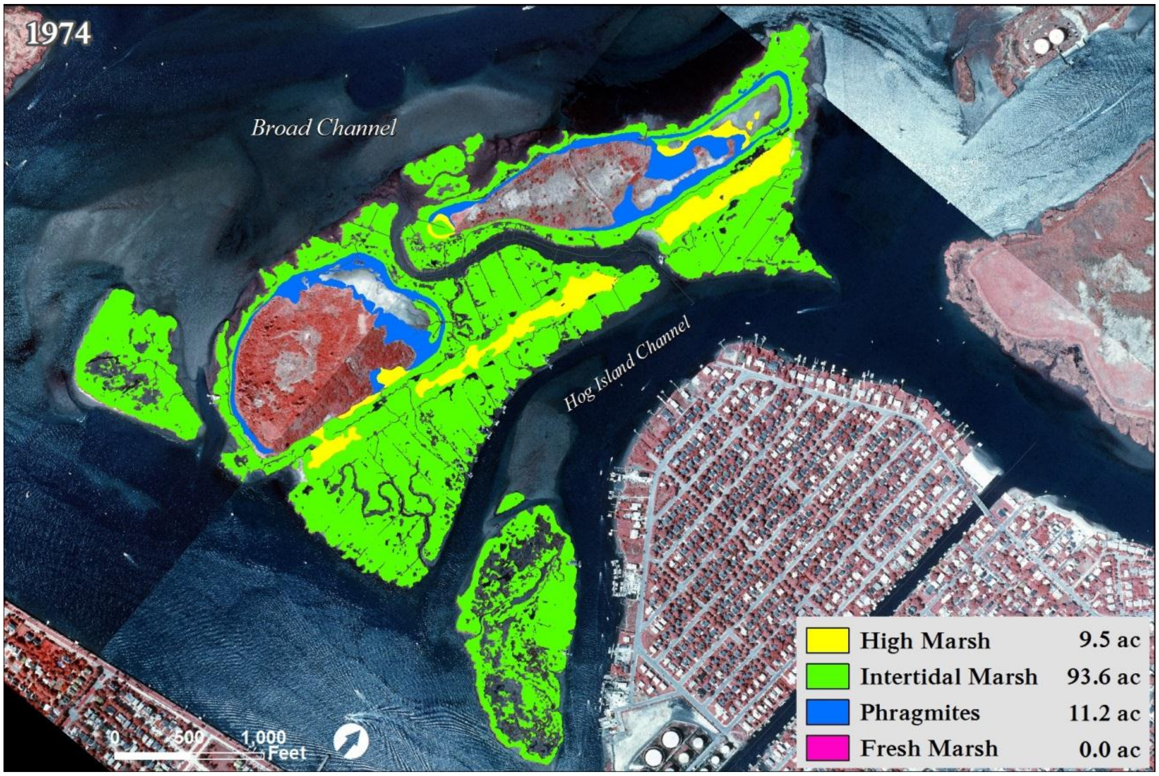
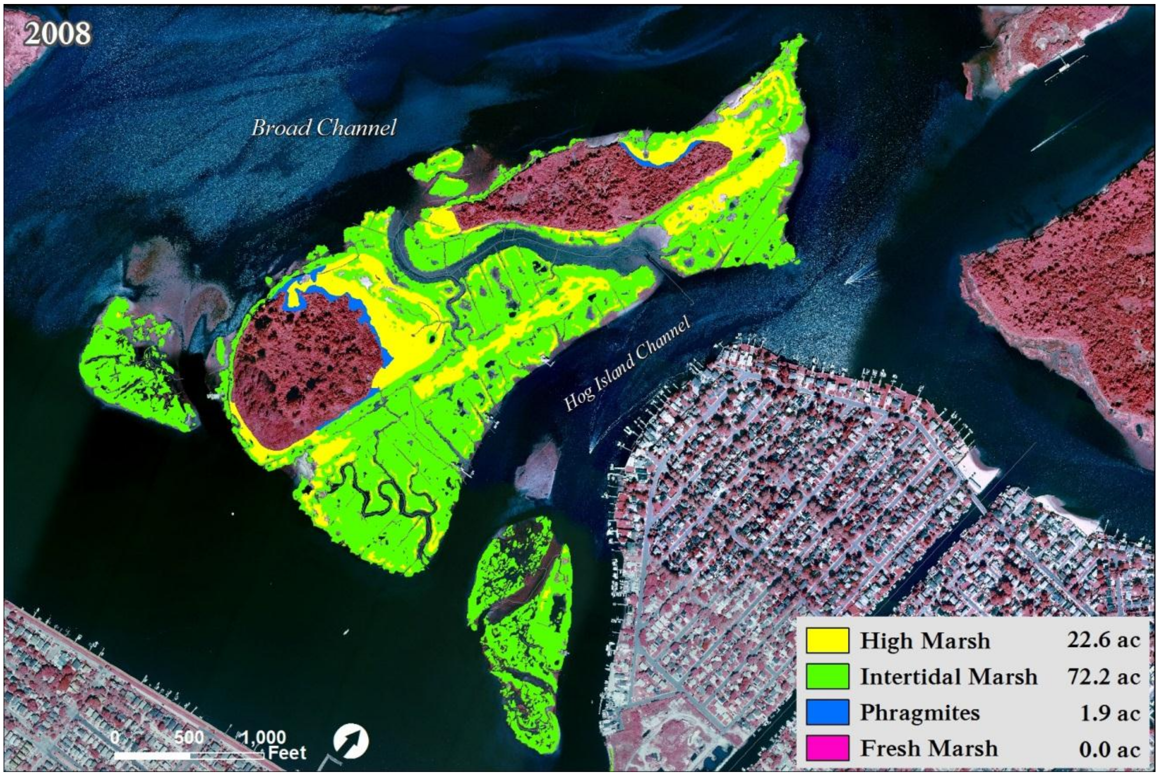


Figure 19: Blackbank Hassock (Complex ID #336) – Conversion of former *Phragmites australis* Stands to Native Marsh

[See Page F1, Appendix I for Locator Map]





South Shore Estuary Trends

The South Shore Estuary was divided into 215 wetland complexes, ranging in size from less than 1 acre to 571 acres of vegetated tidal wetlands. The estuary was divided into three reaches, East Rockaway Inlet to Fire Island Inlet, Fire Island Inlet to Smith Point County Park, and Moriches and Shinnecock Bays, to facilitate interpretation of the trends in tidal wetland area between 1974 and 2008. At the estuary level, the acreage of intertidal marsh habitats remained roughly consistent (-0.6% loss) and high marsh habitats decreased by approximately 29.7% from 1974 to 2008) (Table 13). However, as will be discussed further, these numbers mask tremendous spatial variation in the distribution and magnitude of changes in intertidal and high marsh areas within the South Shore Estuary. Areas classed as coastal fresh marsh in 1974 decreased by an estimated 42.3% by 2008. *Phragmites australis* decreased by 11.2%; as discussed previously, there were large areas of *Phragmites australis* on former dredge spoil sites that converted to high and intertidal marsh presumably due to sea level rise or restoration of tidal inundation. Overall, there was an 11.2%, or 1,627.0 acre, loss of native marsh habitats throughout the South Shore Estuary. Accounting for the modest decline in *Phragmites australis*-dominated areas, the South Shore Estuary had an overall reduction of vegetated areas of 11.2% or 1,845.8 acres.

Table 13: Tidal Wetland Area Change (1974-2008) in the South Shore Estuary by Cover Type

Wetland Type	1974 Wetland Area (acres)	2008 Wetland Area (acres)	Change (%)
Intertidal Marsh	9,404.4	9,344.5	-0.6
High Marsh	4,856.8	3,414.8	-29.7
Fresh Marsh	295.8	170.7	-42.3
Marsh Subtotal	14,557.0	12,930.0	-11.2
Phragmites australis	1,839.0	1,620.2	-11.9
Vegetated Area Total	16,525.3	14,628.4	-11.3

As shown in Table 14, the patterns in the gain and loss of marsh types varied between the three reaches of the South Shore Estuary. Intertidal marsh decreased by -7.4% between East Rockaway Inlet and Fire Island Inlet through the conversion to unvegetated pannes, ponds, or mudflats, increased by +99.4% between Fire Island Inlet and Smith Point County Park, and increased by +18.9% in Moriches and Shinnecock Bays. High marsh decreased by -33.8% within the East Rockaway Inlet to Fire Island Inlet and -35.5% within Fire Island Inlet to Smith Point County Park, and decreased by a lesser extent (-11.3%) in Moriches and Shinnecock Bays. Coastal fresh marsh habitats decreased greatly in each of the three reaches resulting in an overall loss of these habitats within the estuary of -42.3%. *Phragmites australis* decreased by -36.4%

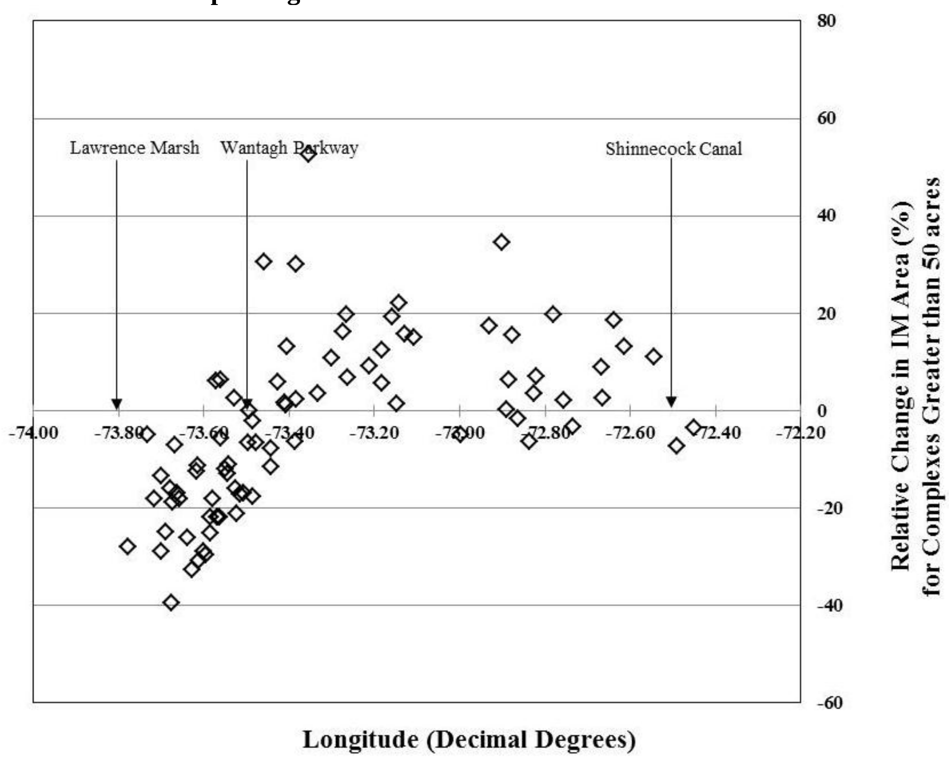
between East Rockaway Inlet and Fire Island Inlet, increased by +20.1% between Fire Island Inlet and Smith Point County Park, and decreased by -35.0% in Moriches and Shinnecock Bays.

Table 14: Tidal Wetland Area Change (1974-2008) Within Each Reach of the South Shore Estuary by Class

SSE Reach	Wetland Type	1974 Area (acres)	2008 Area (acres)	Change (%)
East Rockaway Inlet to Fire Island Inlet	Intertidal Marsh	8,098.7	7,500.8	-7.4
	High Marsh	2,306.1	1,526.8	-33.8
	Fresh Marsh	2.4	0.0	-100.0
	Marsh Subtotal	10,407.1	9,027.6	-13.3
	Phragmites australis	582.3	370.4	-36.4
	Vegetated Area Total	10,989.4	9,398.0	-14.5
Fire Island Inlet to Smith Point County Park	Intertidal Marsh	361.6	721.2	+99.4
	High Marsh	1,547.7	998.3	-35.5
	Fresh Marsh	284.3	165.9	-41.6
	Marsh Subtotal	2,193.7	1,885.3	-14.1
	Phragmites australis	786.1	944.0	+20.1
	Vegetated Area Total	2,979.8	2,829.3	-5.1
Moriches and Shinnecock Bays	Intertidal Marsh	944.1	1,122.5	+18.9
	High Marsh	1,003.0	889.7	-11.3
	Fresh Marsh	9.0	4.8	-46.6
	Marsh Subtotal	1,956.1	2,017.1	+3.1
	Phragmites australis	470.7	305.8	-35.0
	Vegetated Area Total	2,426.8	2,322.9	-4.3
TOTAL	Intertidal Marsh	9,404.4	9,344.5	-0.6
	High Marsh	4,856.8	3,414.8	-29.7
	Fresh Marsh	295.8	170.7	-42.3
	Marsh Subtotal	14,557.0	12,930.0	-11.2
	Phragmites australis	1,839.0	1,620.2	-11.9
	Vegetated Area Total	16,396.0	14,550.2	-11.3

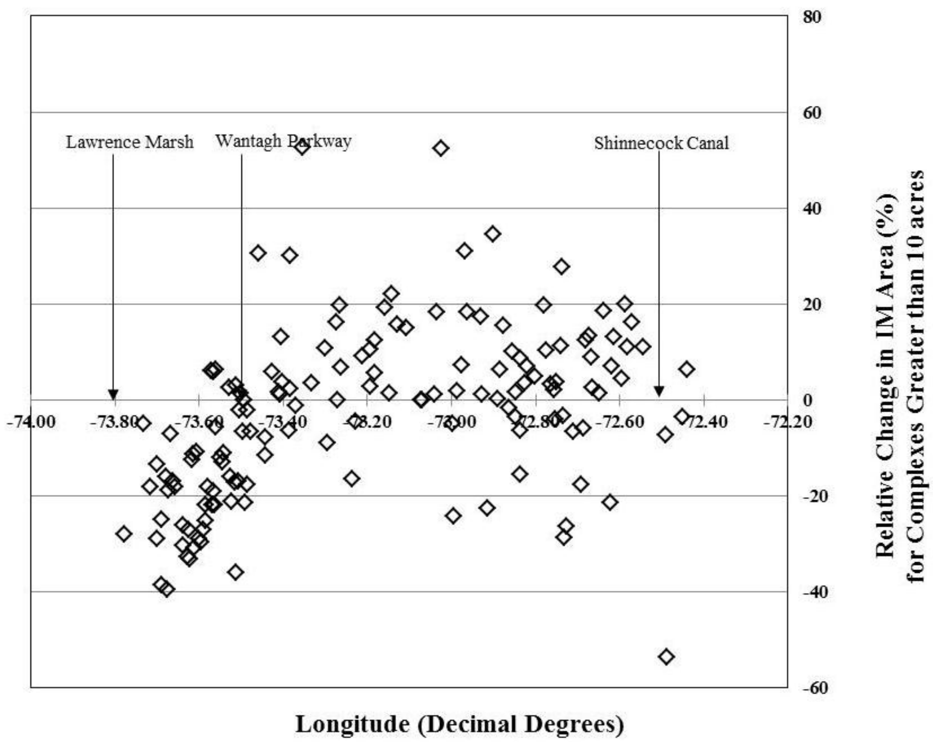
These patterns are also observed at the individual complex level with nearly all marshes located west of the Wantagh Parkway (for wetland complexes greater than 50 acres in area in 1974) showing decreases in the intertidal marsh area through conversion to unvegetated pannes, ponds, and mudflat between 1974 and 2008 (Figure 20). Decreased intertidal marsh area is shown in Figure 20 by a less than 0 value for the change in intertidal marsh between 1974 to 2008 relative to (i.e. as a proportion of) the 1974 total vegetated complex area (IM + HM + FM + *Phragmites australis*). In contrast, complexes in the central and eastern portion of the estuary tended to show gains in intertidal marsh (Figure 20) or a positive value for the change in intertidal marsh area relative to 1974 total vegetated complex area. The increase in intertidal marsh area in the central and eastern reaches of the estuary is due largely to the subsidence of high marsh habitats. This general relationship holds when the analysis is expanded to all wetland complexes greater than 10 acres in size (Figure 21). However, smaller wetland complexes are more likely to be susceptible to large gains or losses in marsh area due to the influence of local variability in sediment supply, erosional conditions, and other environmental factors. Accordingly, there is greater variability in the intertidal marsh loss rates in Figure 21 compared to Figure 20, particularly in the central and eastern portions of the South Shore Estuary.

Figure 20: Relative change in intertidal marsh area compared to longitude in the South Shore Estuary for complexes greater than 50 acres in 1974 area



Note: Change in intertidal marsh (Δ IM from 1974 to 2008) is relative to (i.e. as a proportion of) 1974 total vegetated complex area (IM + HM + FM + *Phragmites australis*). Longitude selected at the polygon centroid for each wetland complex.

Figure 21: Relative change in intertidal marsh area compared to longitude in the South Shore Estuary for complexes greater than 10 acres in 1974 area



Note: Change in intertidal marsh (Δ IM from 1974 to 2008) is relative to (i.e. as a proportion of) 1974 total vegetated complex area (IM + HM + FM + *Phragmites australis*). Longitude selected at the polygon centroid for each wetland complex.

As described in previously, wetland complexes with the greatest areas of high marsh in 1974 were predominantly located in the central and eastern portion of the South Shore Estuary and the Peconic Estuary (Table 5 and Table 6). In these central and eastern South Shore complexes, high marsh also comprised a greater proportion of total vegetated area in 1974 (Table 15). The greater relative abundance of high marsh compared to total marsh area in the central and eastern South Shore estuary in 1974 could be due to 1) greater historical filling of high marsh habitats in the western South Shore estuary, 2) greater historical abundance of high marshes in the central and eastern South Shore estuary resulting from increased sediment supply from larger river and stream systems (i.e. the Connetquot and Carmans Rivers) or other environmental factors, 3) inconsistent differentiation of high marsh and intertidal marsh areas in the 1974 mapping effort, or 4) a combination of these factors.

Table 15: High Marsh Proportion of Vegetated Marsh Area in 1974 in Long Island's South Shore Estuary

Estuary	1974 HM Area (acres)	1974 Vegetated Area (acres)	HM : Total 1974 Area
South Shore Estuary	4,856.8	16,396.0	0.30
East Rockaway to Fire Island Inlet	2,306.1	10,989.4	0.21
Fire Inlet to Smith Point	1,547.7	2,979.8	0.53
Moriches and Shinnecock Bays	1,003.0	2,426.8	0.41

In the central and eastern South Shore Estuary, the subsidence or drowning of the abundant high marsh habitats resulted in increases in intertidal marsh (Figure 8) or panne and pond areas (Figure 9). However, due to the reduced relative abundance of high marshes in the western South Shore Estuary, similar environmental stressors (sea level rise, erosion from vessel wakes, and nutrient loading) result in internal panne formation in intertidal marshes and the erosion/retreat of marsh edges and creek/ditch banks, and, therefore, a decrease in total marsh area.

This mechanism (i.e. lower relative abundance of high marsh in the western South Shore Estuary in 1974) contributes to the general trend of decreasing magnitude of marsh loss moving eastward in the South Shore Estuary, as shown in the variation in marsh loss between the South Shore Estuary Towns (Table 16). However, it is not clear from this study of this mechanism results from natural factors (e.g. increased sediment supply or other environmental factors), anthropogenic impacts (e.g. greater historical filling of high marsh habitats in the western South Shore estuary), or a combination of natural and anthropogenic causes. Furthermore, development density in the western Towns and many other environmental variables with potential impacts on wetland health are also likely to have west-to-east gradients within the estuary.

Marsh loss trends are summarized by Town to provide usable information for land managers and regulators in local municipalities and because these municipal boundaries integrate general patterns in land use and development. As shown in Table 16, rates of marsh loss between 1974 and 2008 tended to decrease from Hempstead (-15.5%) to Southampton, which exhibited a gain in marsh area of 5.9%. The Town of Hempstead comprises approximately 45% of the marsh area in the South Shore Estuary (based on 2008 mapping), yet the loss of 1,060.4 acres of marsh in Hempstead accounted for approximately 66% of the South Shore Estuary's change in marsh area. The Towns of Oyster Bay, Babylon, Islip, and Brookhaven had roughly equivalent percentages of marsh loss ranging from 6.6% to 13.7% and totaling 598.8 acres.

Table 16: Tidal Wetland Area Change in the South Shore Estuary by Town

Municipality	1974 IM+HM+FM (acres)	2008 IM+HM+FM (acres)	Δ IM+HM+FM (acres)	Δ IM+HM+FM (%)
Hempstead	6,824.9	5,764.5	-1,060.4	-15.5
Oyster Bay	910.8	790.5	-120.3	-13.2
Babylon	2,250.3	2,102.5	-147.8	-6.6
Islip	1,044.2	901.3	-142.9	-13.7
Brookhaven	2,312.0	2,124.1	-187.8	-8.1
Southampton	1,051.9	1,114.5	+62.6	+5.9
Total	14,394.1	12,797.4	-1,596.6	-11.1

As stated previously, the patterns of marsh gain and loss varied between the three reaches of the South Shore Estuary. The following sections provide wetland complex examples of the patterns of marsh change in observed in each of the three South Shore reaches and identify complexes with the greatest changes in marsh area.

East Rockaway Inlet to Fire Island Inlet

Wetland complexes in this reach consist mainly of large intertidal marsh islands that have been extensively modified through the dredging of navigational channels and mosquito ditching, and placement of dredge spoils. Figure 17 and Table 18 list the marsh complexes that have sustained the largest reductions in marsh habitat from 1974 through 2008 in both acreage and percent loss, respectively. Lawrence Marsh (ID # 322), which lost 72.3 acres of marsh (11.8% of its 1974 area), and Hewlett Hassock & Nums Marsh (ID # 328), which lost 26.6 acres of its 1974 marsh area (34.9%) are shown in Figure 22 and Figure 23, respectively. Captree Island & Seaganus Thatch (ID # 410) lost 56.8 acres of marsh (9.5% of its 1974 area) with high marsh area decreasing by 65.1% (276.9 to 96.6 acres) and intertidal marsh increasing by 38.9% (317.6 acres to 441.6 acres) (Figure 24). Other East Rockaway to Fire Island Inlet marshes with large reductions in marsh acreage or percentage of 1974 marsh area are shown in Figure 8 (Cedar & Nezaras Islands, ID # 401), Figure 11 (Pine Marsh, ID # 356), Figure 12 (Tobay Sanctuary & Marsh Island North of State Boat Channel, ID # 385 and 386), and Figure 14 (Cuba, Middle, and East Islands, ID # 367). These marsh complexes show typical indications of intertidal marsh loss including panne formation, creek and channel widening, edge retreat, thinning of peninsulas, scalloping of the marsh edge, and loss of small marsh islands.

Table 17: Complexes with Largest Tidal Wetland Loss between East Rockaway Inlet and Fire Island Inlet

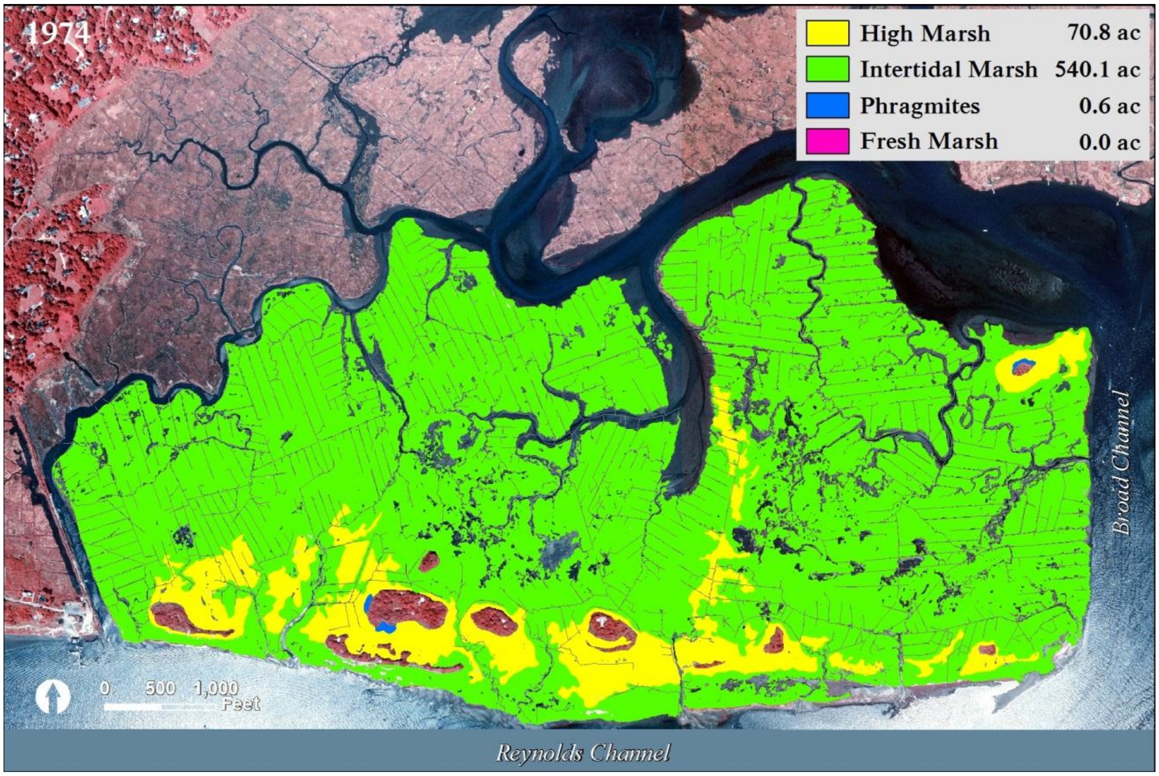
Complex (ID #)	1974 IM + HM + FM (acres)	2008 IM + HM + FM (acres)	Δ IM + HM +FM (acres)	Δ IM + HM +FM (%)
Marsh Islands North of State Boat Channel (386)	607.9	504.6	-103.3	-17.0%
Lawrence Marsh (322)	610.8	538.5	-72.3	-11.8%
Cuba, Middle & East Islands (367)	238.5	176.2	-62.3	-26.1%
Captree Island & Seaganus Thatch (410)	594.4	537.6	-56.8	-9.6%
Jones, Middle & West Cow Islands (364)	374.0	318.8	-55.2	-14.8%
Big Cow Island (363)	308.4	253.4	-55.0	-17.8%
South Line Island (382)	362.4	312.3	-50.2	-13.8%
Cedar & Nezeras Islands (401)	583.5	541.4	-42.1	-7.2%
Pine Marsh (356)	204.2	163.7	-40.5	-19.8%
Deep Creek Meadow & Snipe Island (366)	194.7	157.2	-37.6	-19.3%

Table 18: Complexes with Largest Tidal Wetland Loss by Percentage between East Rockaway Inlet and Fire Island Inlet

Complex (ID #)	1974 IM + HM +FM (acres)	2008 IM + HM + FM (acres)	Δ IM + HM +FM (%)	Δ IM + HM +FM (acres)
Hewlett Hassock & Nums Marsh (328)	76.1	49.5	-34.9	-26.6
Olivers Island (373)	39.4	25.8	-34.5	-13.6
West Meadow Island (334)	19.2	13.2	-31.5	-6.1
Jones Beach West Tip (371)	29.9	20.5	-31.3	-9.4
Long Meadow & Middle Islands (346)	72.4	50.3	-30.6	-22.1
Ingraham Hassock (345)	41.8	30.0	-28.2	-11.8
East Channel Islands (341)	130.4	93.8	-28.1	-36.6
Seadog Island (351)	136.3	99.2	-27.2	-37.1
Cinder & North Cinder Islands (344)	139.0	101.4	-27.0	-37.6
Cuba, Middle & East Islands (367)	238.5	176.2	-26.1	-62.3

Figure 22: Lawrence Marsh (Complex ID #322) – 2nd Largest Tidal Wetland Area Loss (East Rockaway to Fire Island Inlet)

[See Page F1, Appendix I for Locator Map]



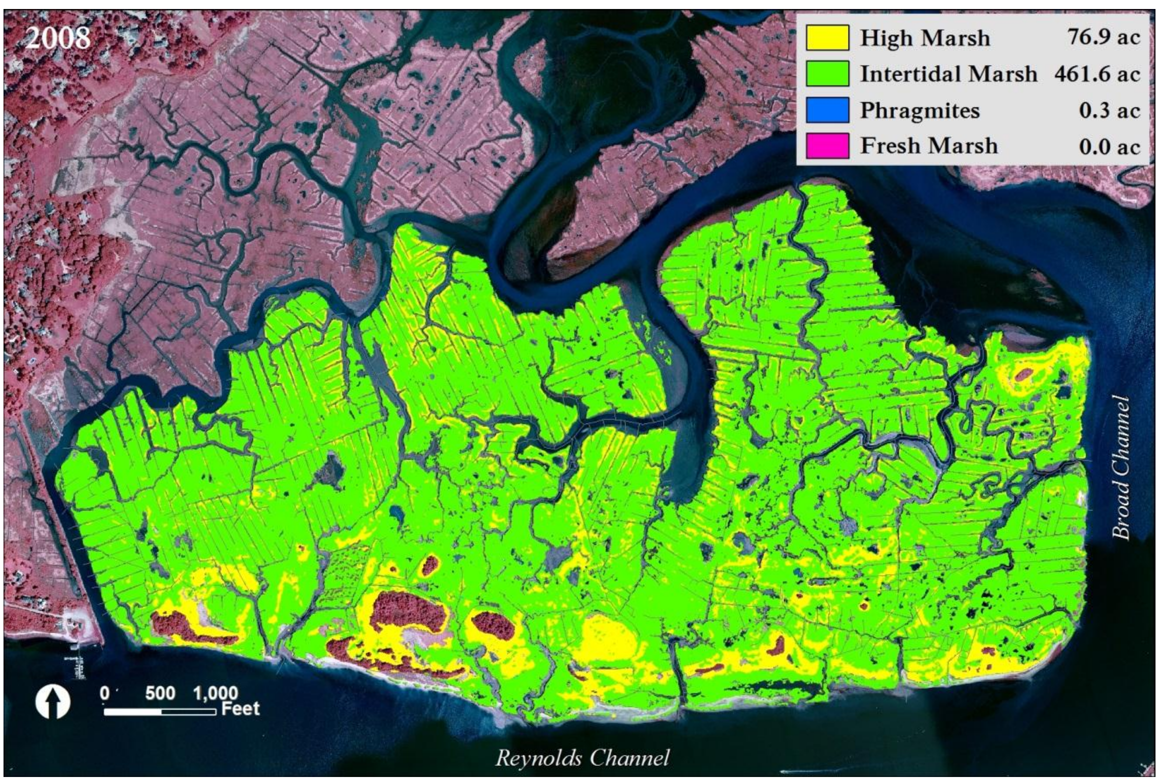
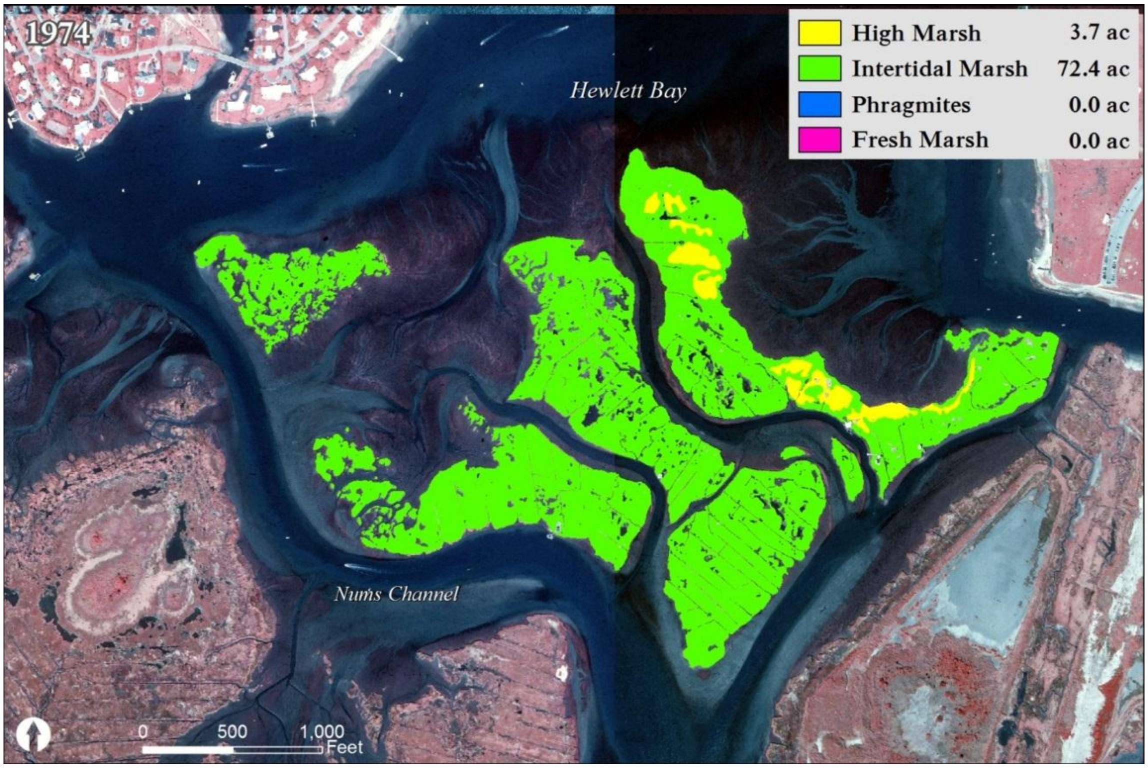


Figure 23: Hewlett Hassock & Nums Marsh (Complex ID #328) – Largest Tidal Wetland Percentage Loss (East Rockaway to Fire Island Inlet)

[See Page F1, Appendix I for Locator Map]



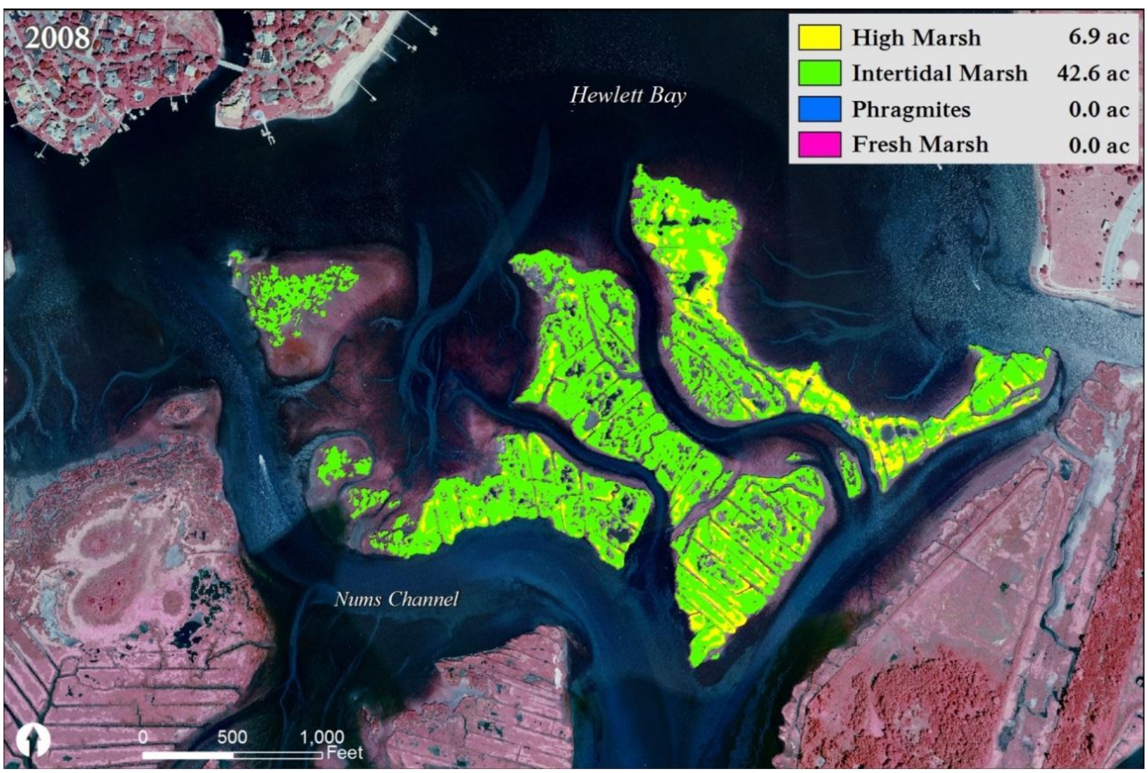


Figure 24: Captree Island & Seaganus Thatch (Complex ID #410)
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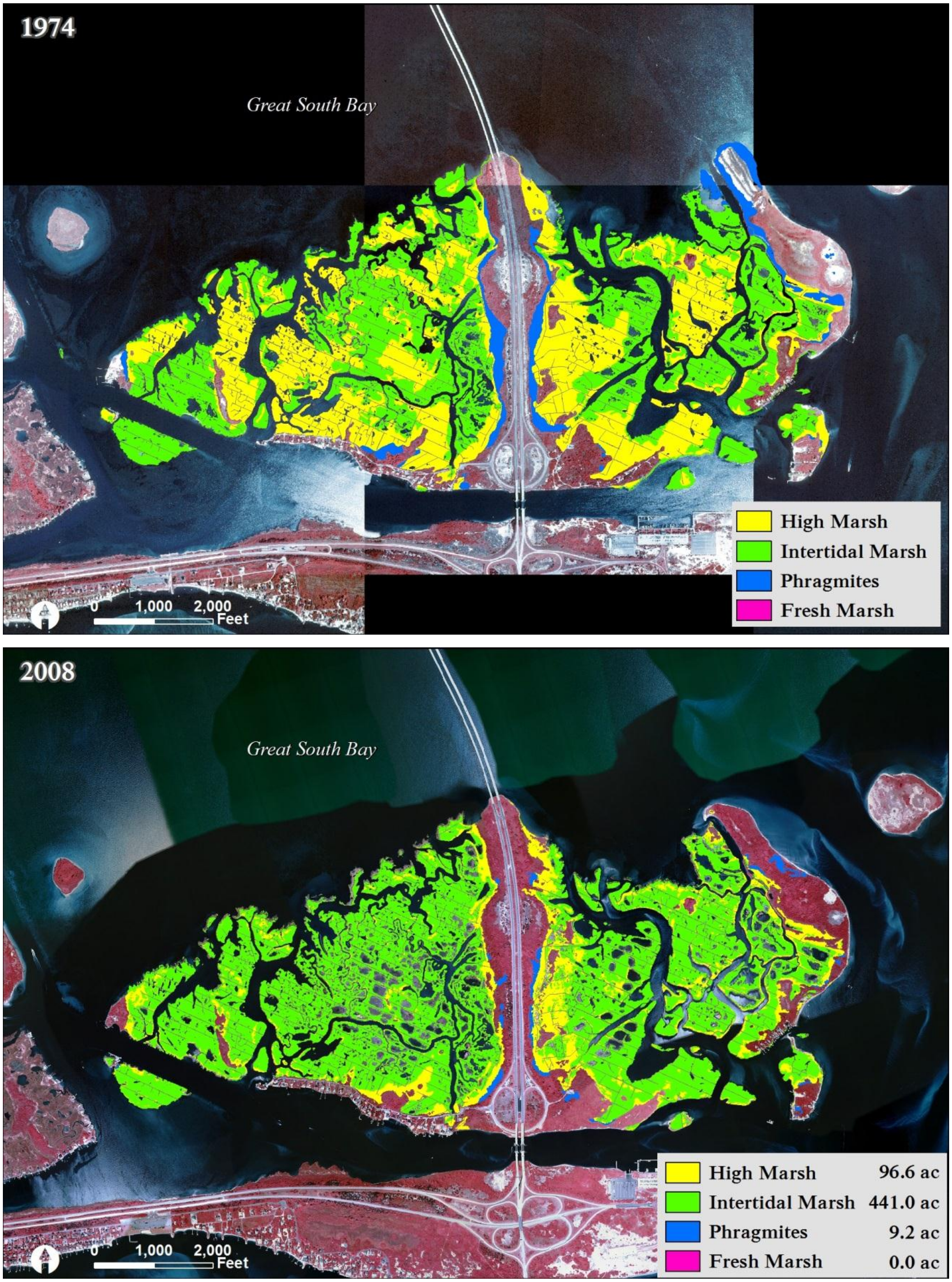


Fire Island Inlet to Smith Point County Park

Dominant patterns in the gain and loss of marsh types between Fire Island Inlet and Smith Point County Park included 1) drowning or waterlogging of this reach's extensive high marsh areas and conversion to either panne or intertidal marsh, 2) increases in intertidal marsh area at the expense of former high marsh areas, 3) expansion of *Phragmites australis* leading to large reductions in coastal fresh marsh habitats and encroachment on high marsh areas proximal to groundwater or fresh surface water inflows, and 4) some expansion of high and intertidal marsh habitats into former *Phragmites australis* areas located on previously disturbed sites. Table 19 and Table 20 list the marsh complexes that have sustained the largest reductions in marsh habitat from 1974 through 2008 in both acreage and percent loss, respectively. The marshes presented in Table 19 account for 223.6 acres of lost intertidal, high, and coastal fresh marsh.

The conversion of native high marsh to intertidal marsh and pannes is clearly shown at Fireplace Neck (ID # 461, Figure 25, -127.06 acres of high marsh and +106.4 acres of intertidal marsh), Gardiners County Park (ID # 418, Figure 26, -7.5 acres of high marsh and +11.6 acres of intertidal marsh), Pepperidge State Tidal Wetlands (ID # 434, Figure 27, -37.9 acres of high marsh and +19.2 acres of intertidal marsh), Lymans Marsh (ID # 457, Figure 28, -3.9 acres of high marsh and +3.8 acres of intertidal marsh), and Smith Point County Marina (ID #465, Figure 29, -1.5 acres of high marsh and +9.9 acres of intertidal marsh). *Phragmites australis* expansion has overtaken high marsh areas at Robert Moses State Park (ID # 421, Figure 30, +10.9 acres of *Phragmites australis* and -21.6 acres of intertidal and high marsh) and coastal fresh marsh habitats at Fireplace Neck (ID # 461, Figure 25), Pepperidge State Tidal Wetlands (ID # 434, Figure 27), and Swan River (ID # 453, Figure 31, +4.4 acres of *Phragmites australis*, -7.8 acres of coastal fresh marsh and -7.4 acres of intertidal and high marsh).

Table 21 lists the marsh complexes that have exhibited the largest increases in marsh habitat from 1974 through 2008. Interestingly, two of the marsh complexes described above, Gardiners County Park (ID # 418, Figure 26) and Smith Point County Marina (ID # 465, Figure 29), exhibit apparent gains in total intertidal, high, and coastal fresh marshes as it appears that native marsh or mixed *Iva frutescens* or *Phragmites australis* stands have expanded into some former *Phragmites australis* areas. However, these marsh complexes clearly show deterioration of the high marsh in the interior of these complexes and conversion to intertidal marsh (Gardiners County Park) or panne and intertidal marsh (Smith Point County Park Marina). Heckscher State Park (ID # 430) provides another example of intertidal and high marsh expansion into *Phragmites australis* stands, as 13.2 acres of native marsh are now present within this wetland (Figure 32).

Table 19: Complexes with Largest Tidal Wetland Loss between Fire Island Inlet and Smith Point County Park

Complex (ID#)	1974 IM + HM + FM (acres)	2008 IM + HM + FM (acres)	Δ IM + HM +FM (acres)	Δ IM + HM +FM (%)
Carmans River East (462)	303.1	251.9	-51.2	-16.9
Fireplace Neck & Carmans River West (461)	279.5	235.6	-43.9	-15.7
Carmans River Upstream FM (463)	97.1	61.6	-35.5	-36.6
East Fire Island (424)	130.3	101.5	-28.8	-22.1
Pepperidge State Tidal Wetlands (434)	96.4	76.0	-20.4	-21.2
Fire Island National Seashore (445)	481.7	459.4	-22.2	-4.6
Robert Moses State Park (421)	23.2	1.6	-21.6	-93.1

Table 20: Complexes with Largest Tidal Wetland Loss (%) between Fire Island Inlet and Smith Point County Park

Complex (ID #)	1974 IM + HM +FM (acres)	2008 IM + HM +FM (acres)	Δ IM + HM +FM (%)	Δ IM + HM +FM (acres)
Robert Moses State Park (421)	23.2	1.6	-93.1	-21.6
Browns River North (438)	14.8	5.0	-66.1	-9.8
Swan River (453)	29.2	14.0	-52.1	-15.2
Mud Creek (454)	35.6	18.5	-48.0	-17.1
Carmans River Upstream FM (463)	97.1	61.6	-36.6	-35.5
Grand Canal & Pickman Wetlands (432)	29.7	19.9	-32.8	-9.7
Hedges Creek (456)	19.7	14.3	-27.4	-5.4

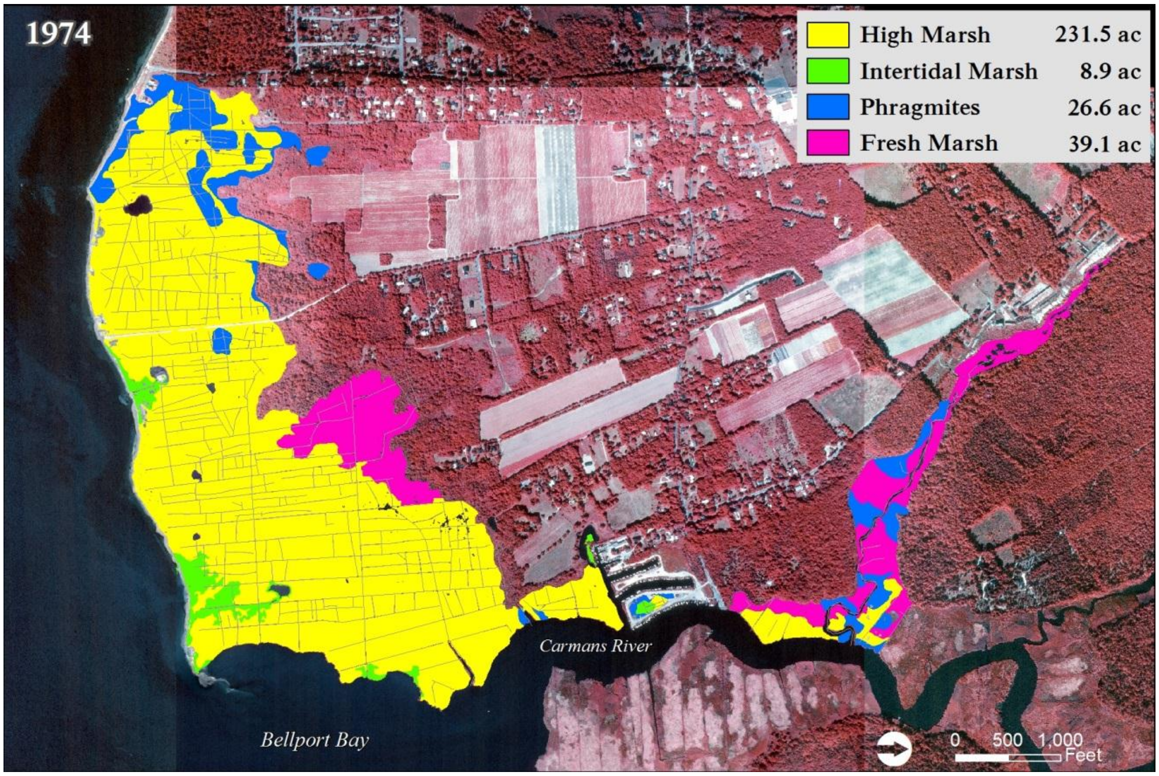
Table 21: Complexes with Largest Phragmites Increase between Fire Island Inlet and Smith Point County Park

Complex (ID #)	1974 Phragmites (acres)	2008 Phragmites (acres)	Δ Phragmites (acres)
Carmans River East (462)	34.8	96.4	61.6
Fireplace Neck & Carmans River West (461)	26.6	60.3	33.6
Carmans River Upstream FM (463)	46.1	61.8	15.7
Pepperidge State Tidal Wetlands (434)	21.8	36.2	14.4
Indian Creek (435)	21.3	35.6	14.3

Table 22: Complexes with Largest Tidal Wetland Increase between Fire Island Inlet and Smith Point County Park

Complex (ID #)	1974 IM + HM +FM (acres)	2008 IM + HM +FM (acres)	Δ IM + HM +FM (acres)
Heckscher State Park FC Wetland (430)	43.3	56.5	13.2
Smith Point County Marina (465)	48.5	57.0	8.5
Stillman Creek (449)	13.1	19.2	6.1
Democrat Point (420)	0.0	6.1	6.1
Gardiners County Park (418)	53.7	57.8	4.1
Abetts Creek (455)	1.8	5.9	4.1

Figure 25: Fireplace Neck and Carmans River West (Complex ID #461)
[See Page E6, Appendix I for Locator Map]



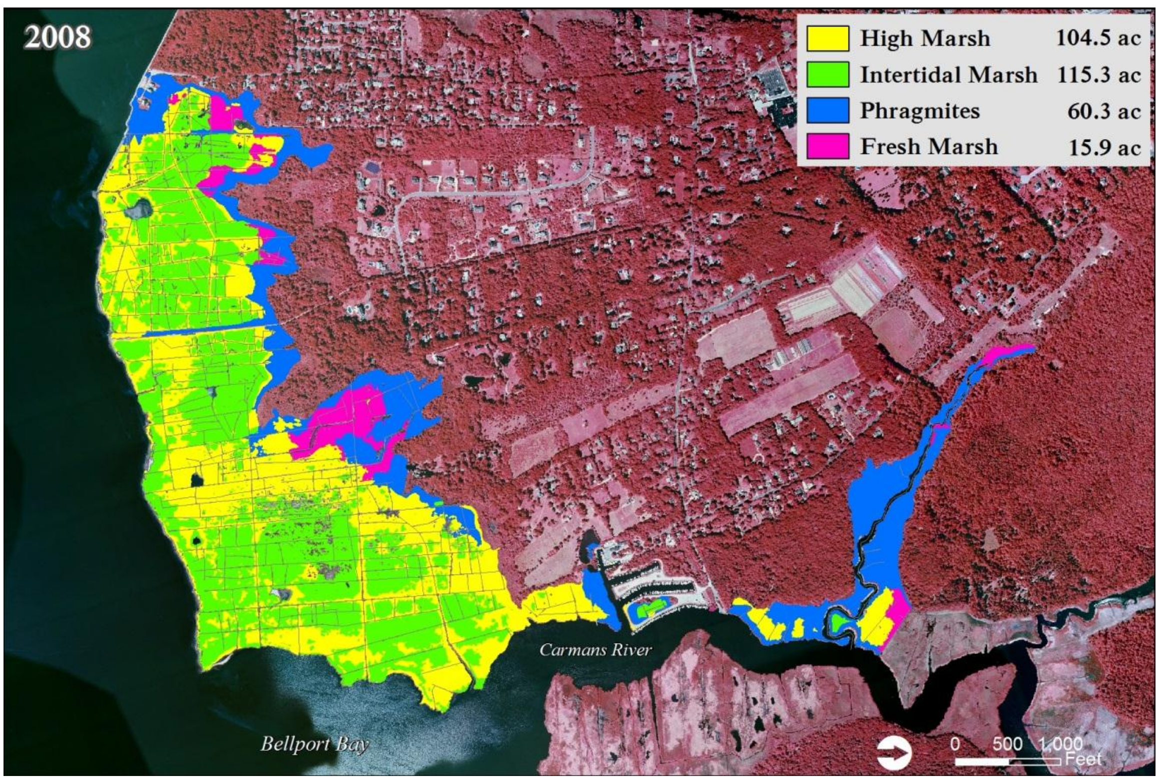


Figure 26: Gardiners County Park (Complex ID #418)

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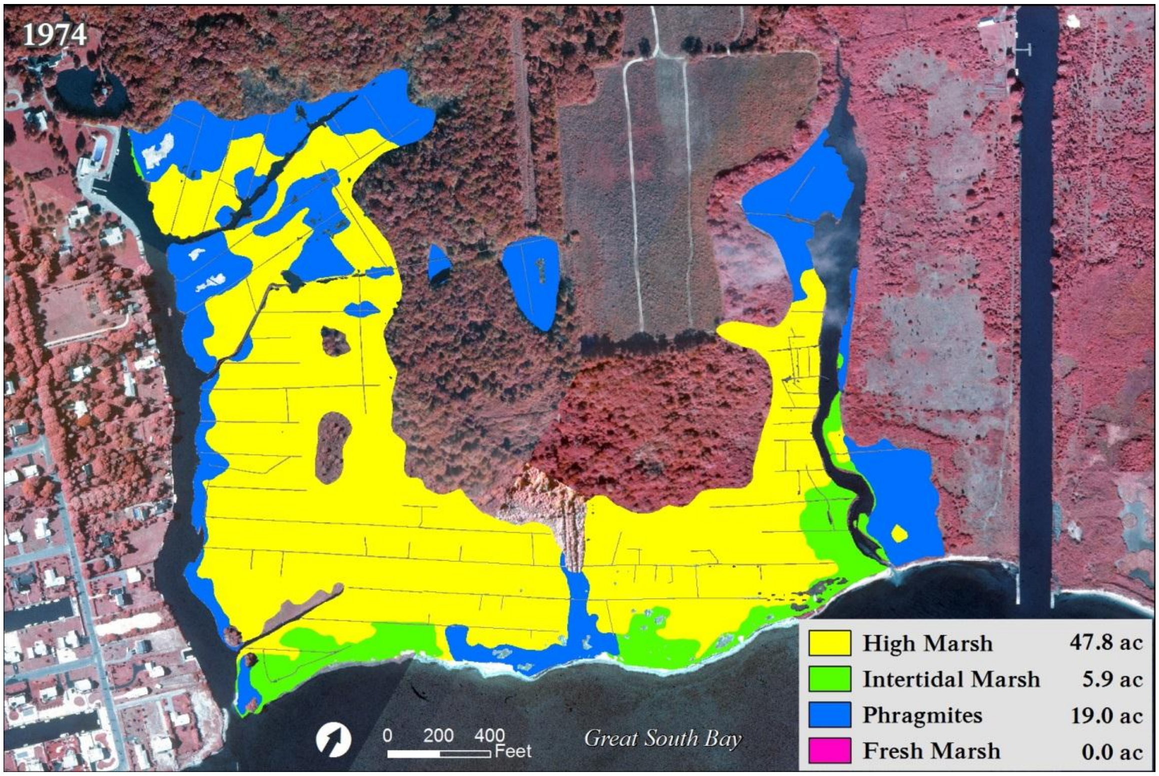

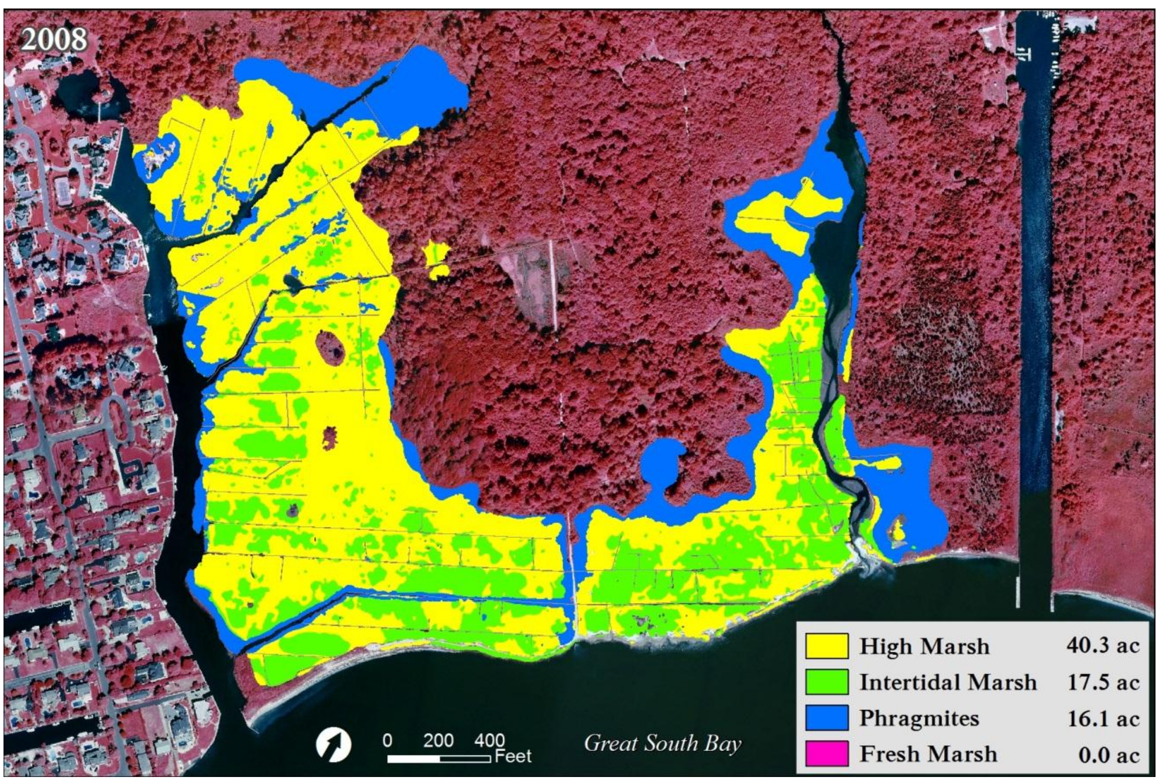

Figure 27: Pepperidge State Tidal Wetlands (Complex ID #434)

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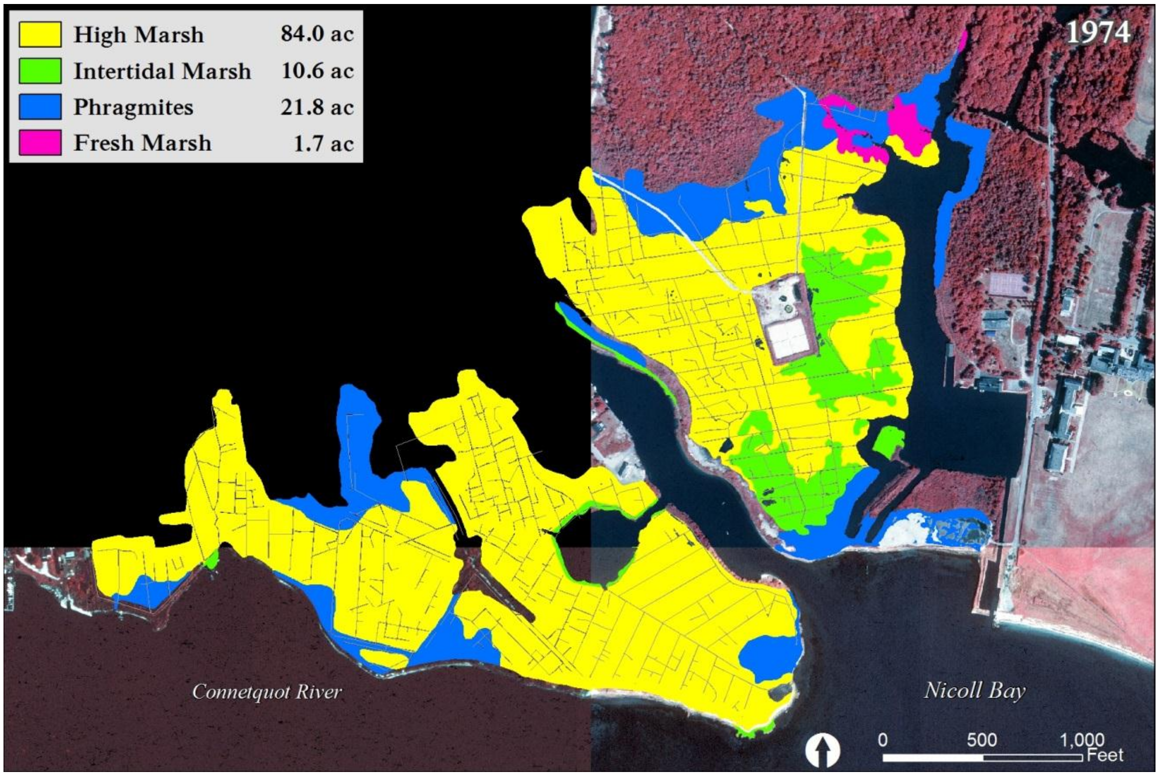

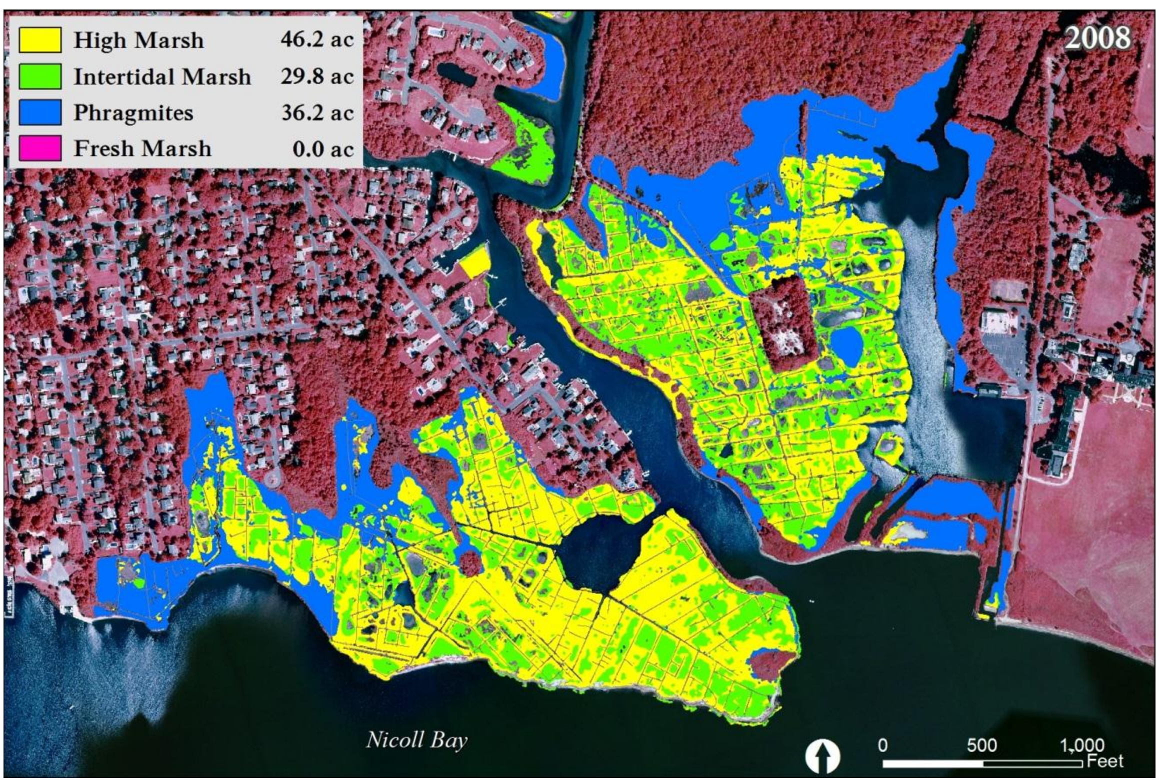

Figure 28: Lymans Marsh (Complex ID #457)
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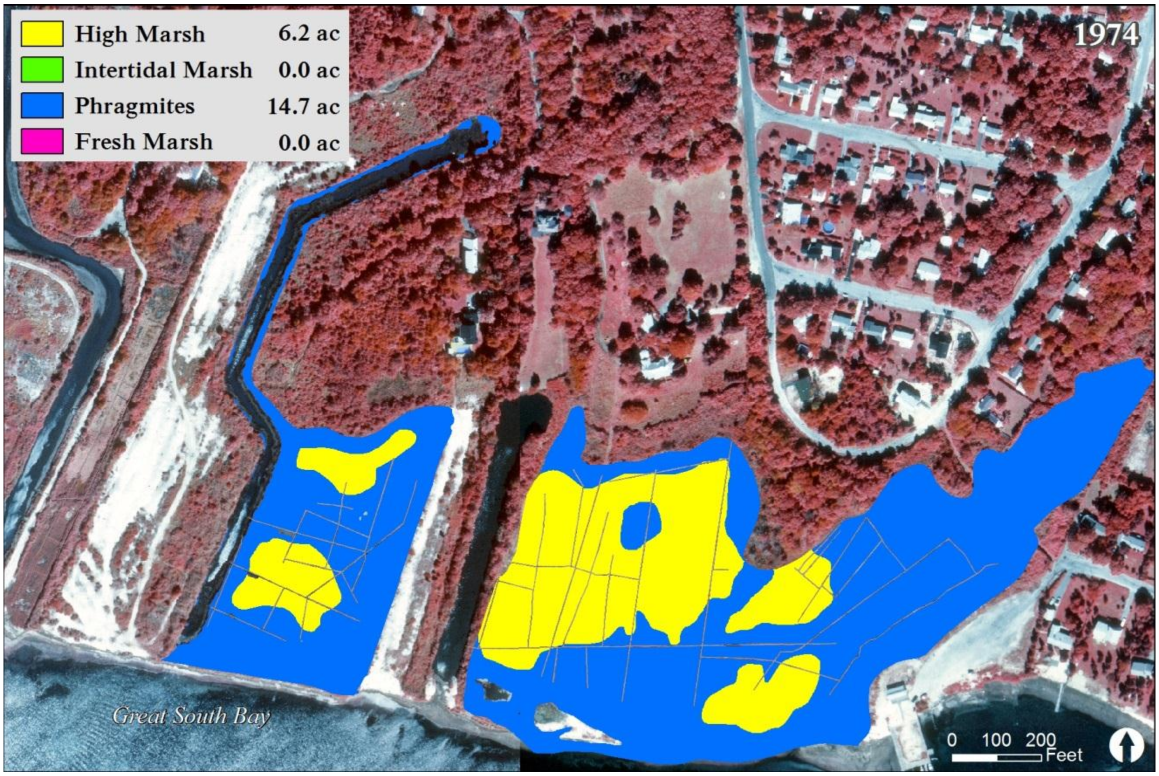

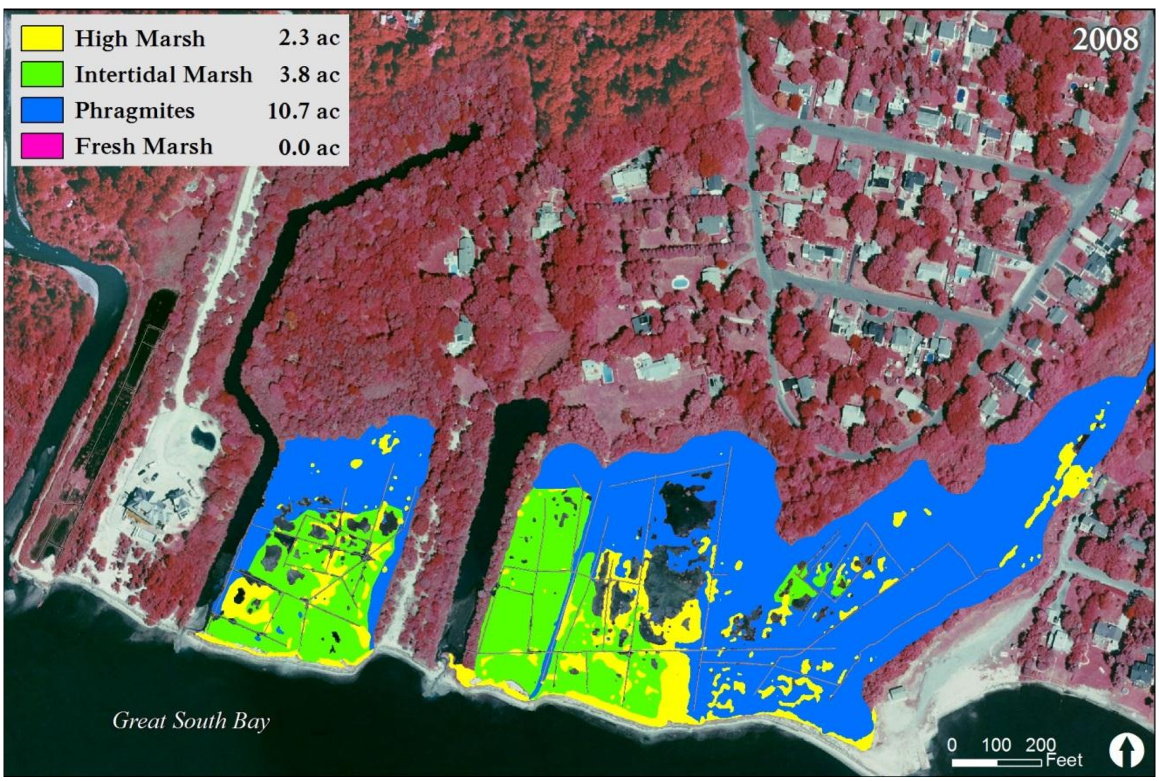

Figure 29: Smith Point County Park Marina (Complex ID #465)

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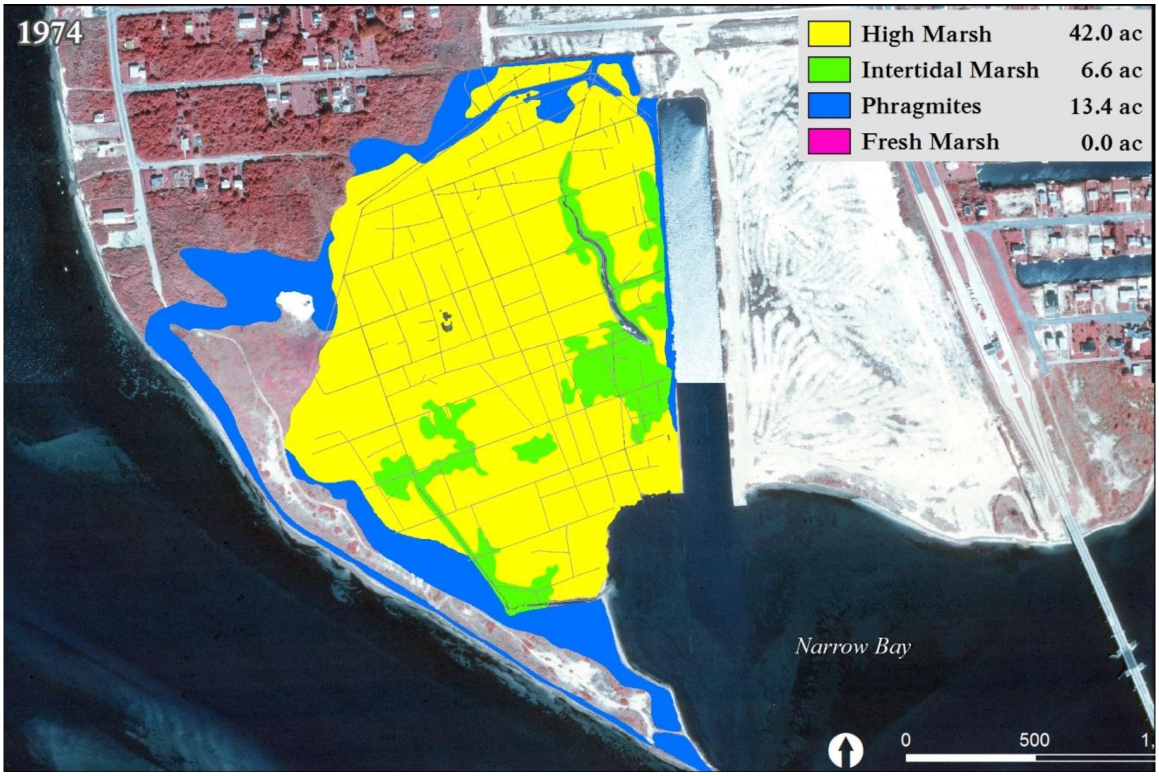

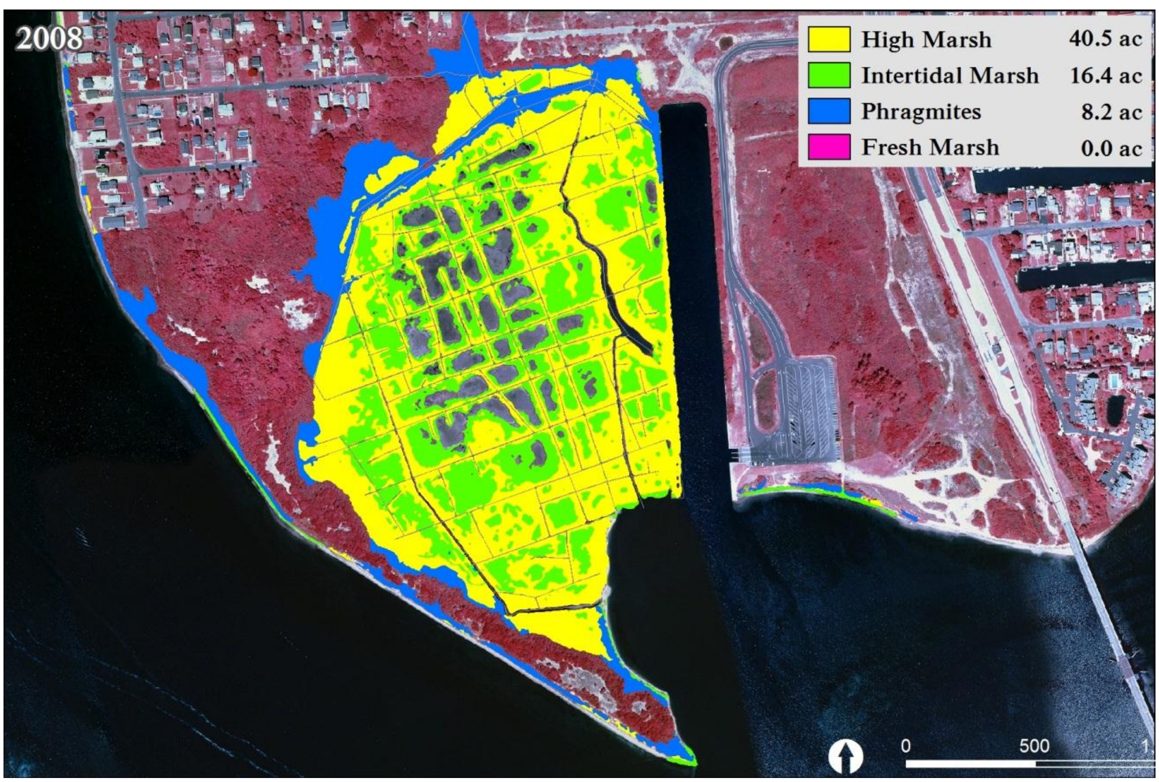

Figure 30: Robert Moses State Park (Complex ID #421)

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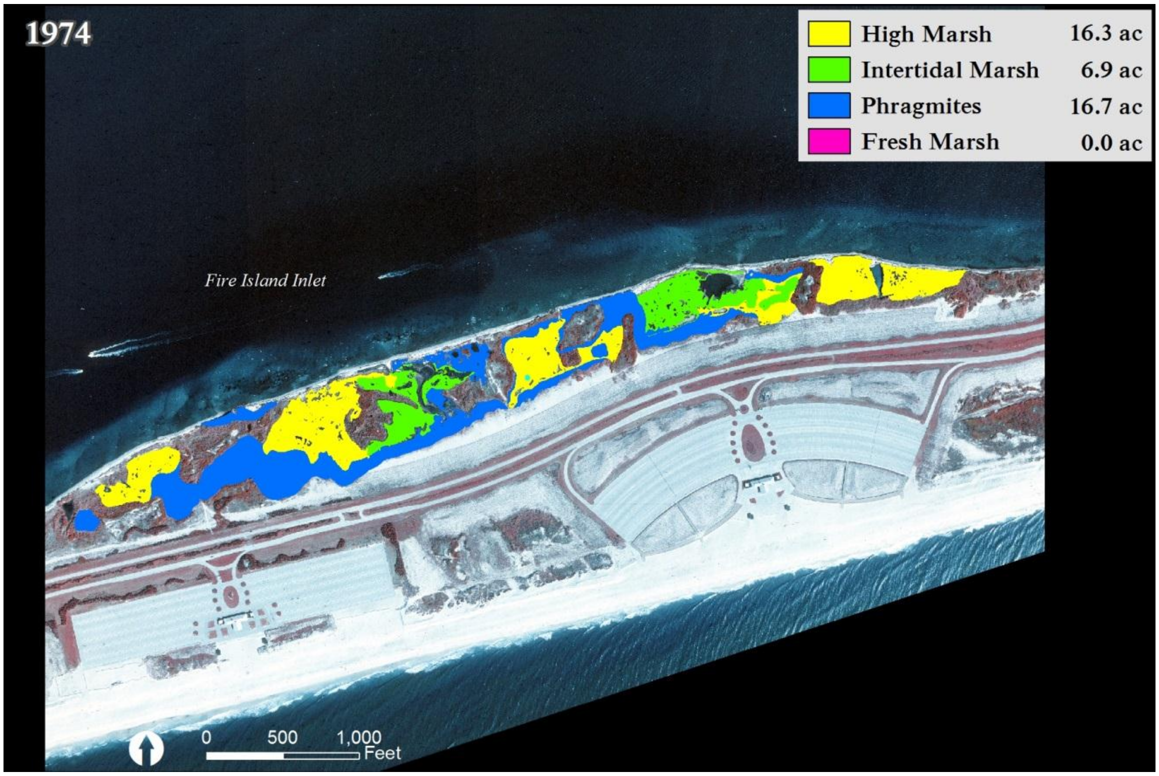

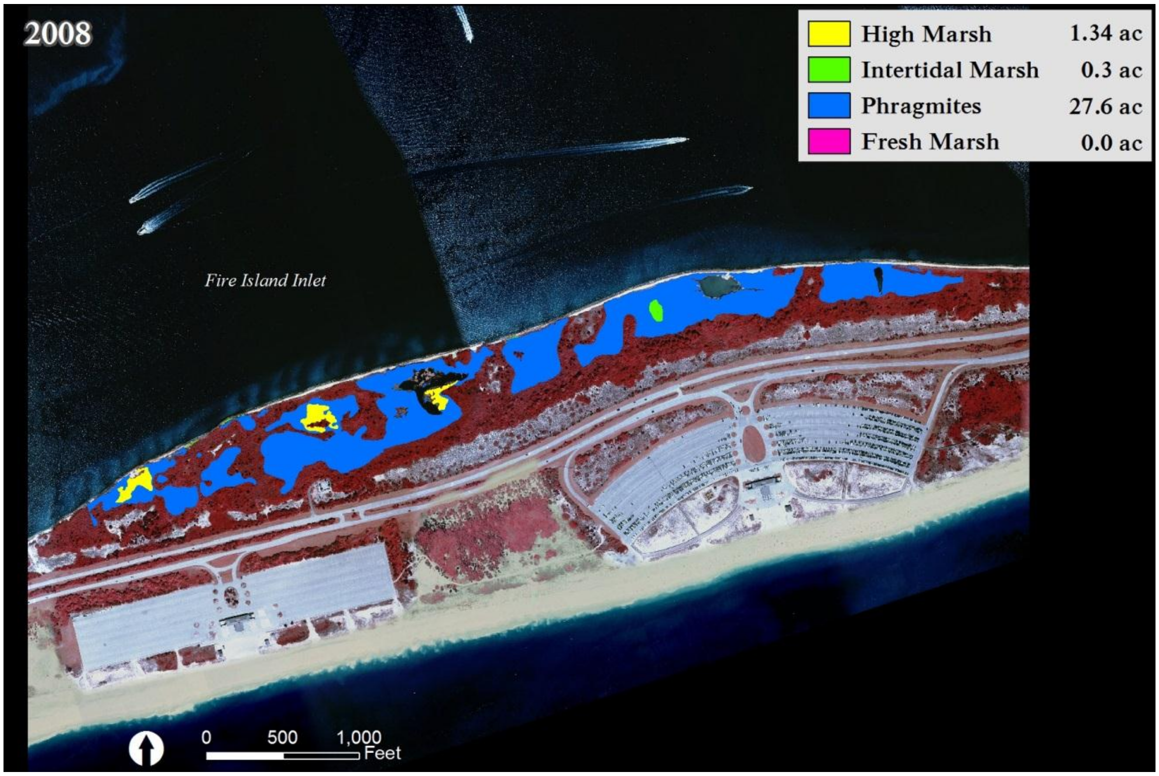

Figure 31: Swan River (Complex ID #453)

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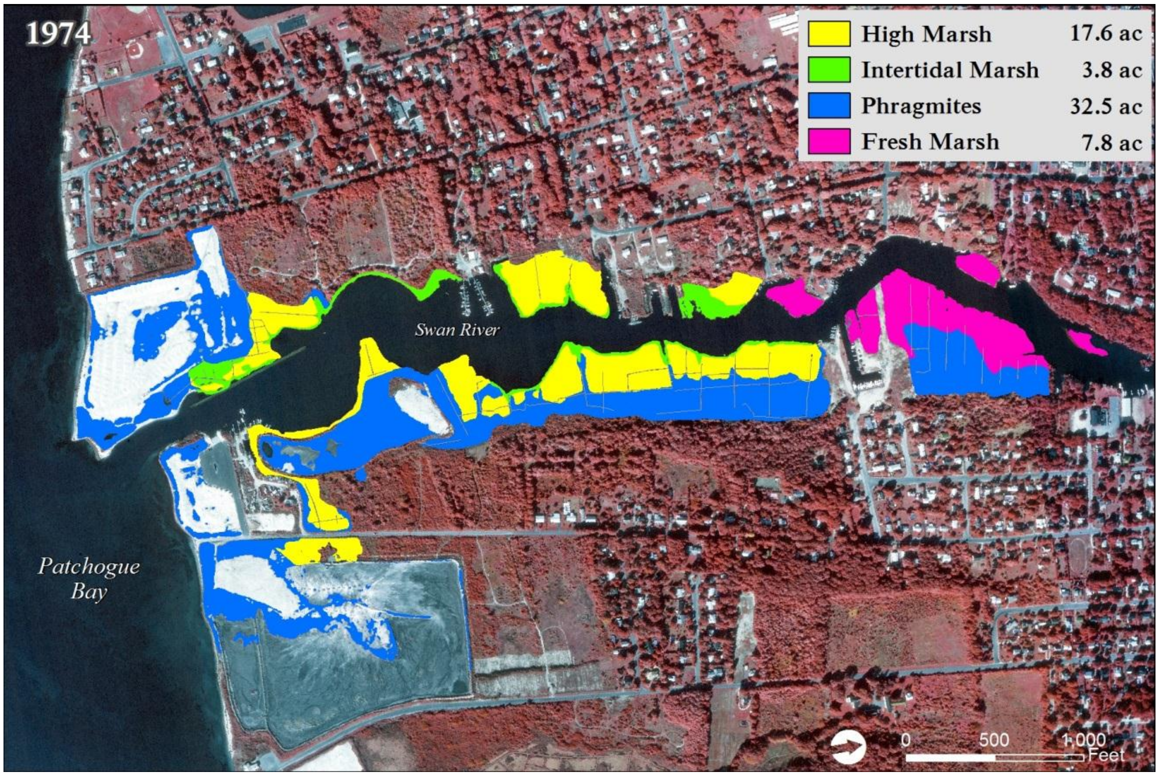

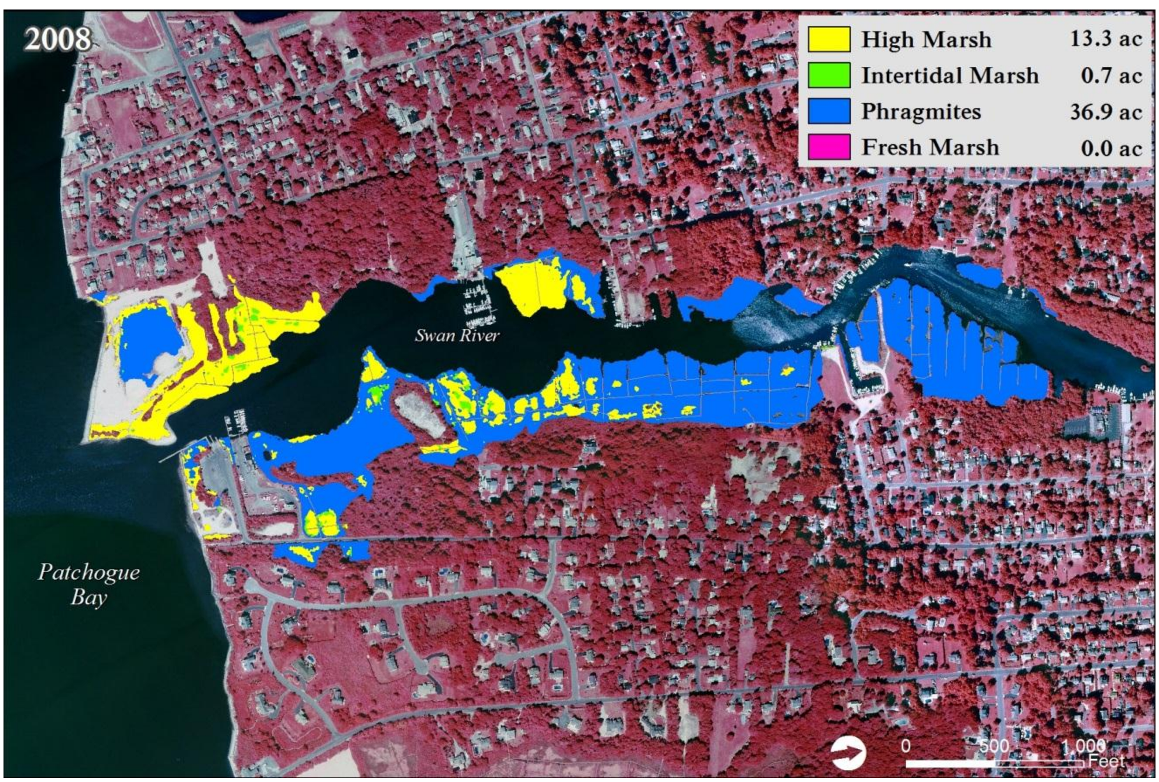

Figure 32: Heckscher State Park FC Wetland (Complex ID #430)
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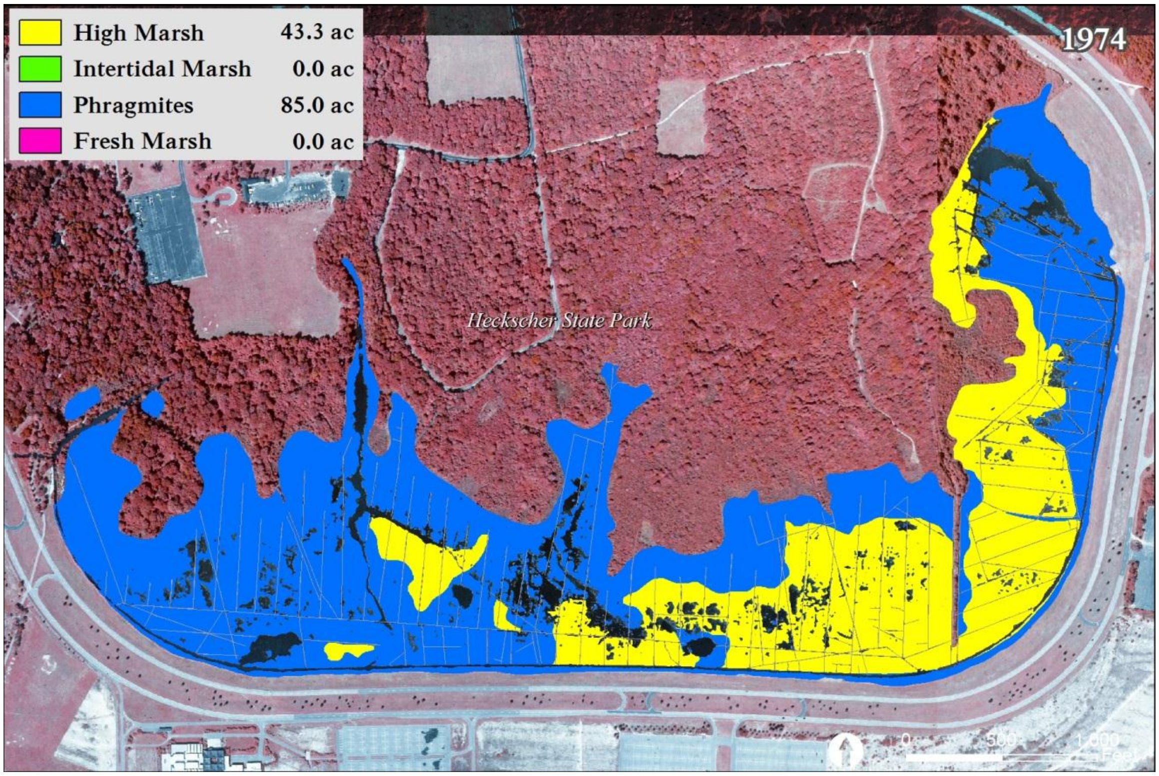
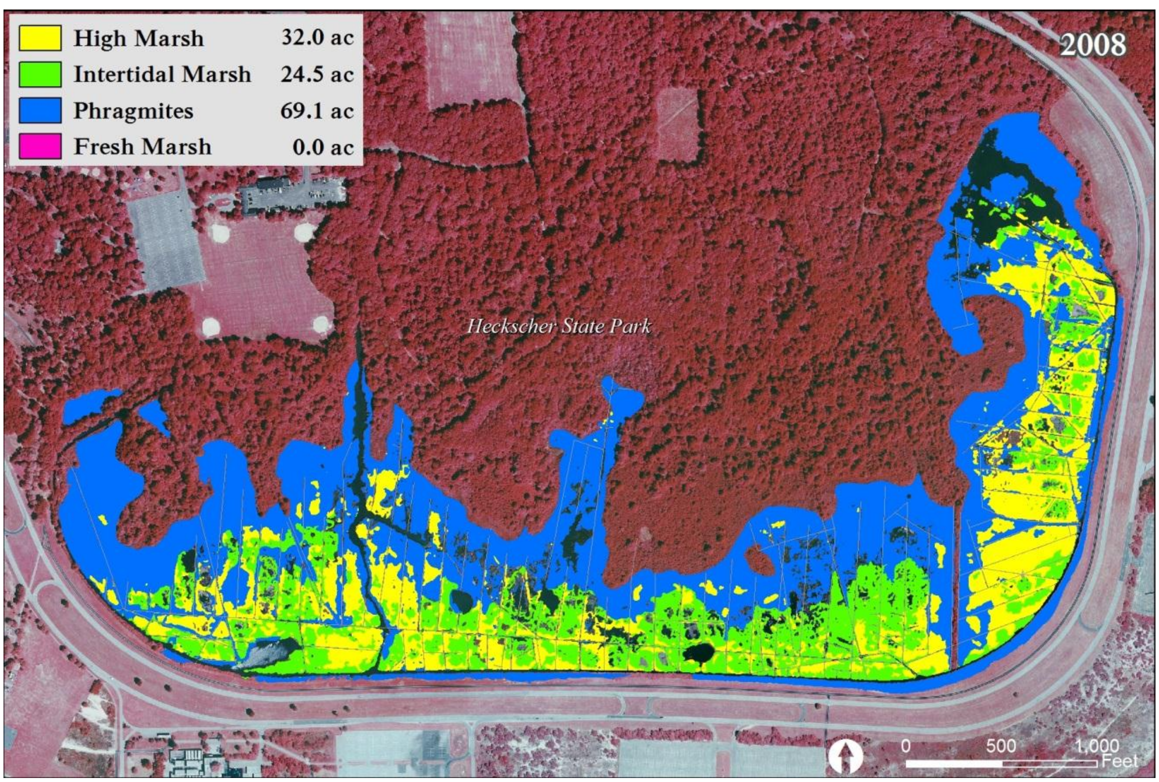




Moriches and Shinnecock Bays

The reduced magnitude of tidal wetlands loss in Moriches and Shinnecock Bays appears to result from 1) conversion of high marsh to intertidal marsh and less extensive internal panne formation than the East Rockaway Inlet to Fire Island Inlet and Fire Island Inlet to Smith Point reaches; 2) reduced loss of intertidal marsh through retreat of the seaward edge; and 3) conversion of *Phragmites australis* or low-lying upland habitats to tidal wetland due to increased tidal inundation caused by either improved tidal exchange between the wetland and the bays or sea level rise. It should be noted that there are locations in Moriches and Shinnecock Bays where the current year mapping identified tidal wetlands that were present, but unmapped, for Year 1974. As a result of more accurate mapping (through computer-automated techniques) for the current year imagery, the increase in vegetated wetlands between 1974 and 2008 observed for Moriches and Shinnecock Bay may be overestimated.

Table 23 and Table 24 list the marsh complexes in Moriches and Shinnecock Bays that have sustained the largest reductions in marsh habitat from 1974 through 2008 in both acreage and percent loss, respectively. The magnitude of the lost wetlands area (Table 23) for these complexes, -7.9 acres to -11.3 acres, is much smaller than that for the complexes with the largest wetland losses in the East Rockaway Inlet to Fire Island Inlet and Fire Island Inlet to Smith Point reaches (Table 17 and Table 19). Moriches Bay and Shinnecock Bay contain complexes with rates of wetland loss comparable to the western reaches (Table 24 compared to Table 18 and Table 20); however, the Moriches Bay and Shinnecock Bay have fewer complexes with loss rates greater than -10%.

Complexes in Moriches Bay and Shinnecock Bay with the greatest acreages of marsh loss, such as Dune Road Marsh East (ID #529, Figure 33), William Floyd Estate (ID # 471, Figure 35), and Ponquogue Islands (ID # 528, Figure 36) exhibit many of the same characteristics of marsh loss observed elsewhere in the South Shore Estuary. The Dune Road Marsh lost 5.7 acres of high marsh (22.5 to 16.9 acres) and 4.0 acres of intertidal marsh (22.1 acres to 18.2 acres) between 1974 and 2008. This complex shows formation of a large panne within the intertidal marsh, retreat of the seaward edge of the marsh, conversion of high marsh to intertidal marsh, as well as apparent landward migration of the tidal wetlands in the southwestern potion of the complex. The William Floyd Estate marsh loss trends are similar to high marsh-dominated complexes between Fire Island Inlet and Smith Point County Park, as 21.7 acres of high marsh were lost (81.9 to 60.2 acres) and converted to several large panne areas, *Phragmites australis* (9.5 acres to 22.8 acres) and intertidal marsh (85.0 to 97.4 acres). The complex with the largest percentage of tidal wetlands loss in Moriches and Shinnecock Bays, Ponquogue Islands (Figure 36), lost 9.9 acres of the 11.0 acres of intertidal marsh present in 1974 and emphasizes both the importance of local patterns of sediment supply and erosion for maintaining marsh area and the susceptibility of small, intertidal marsh-dominated islands to navigation impacts.

Table 25 lists the marsh complexes that have exhibited the largest increases in marsh habitat acreage from 1974 through 2008 in Moriches and Shinnecock Bays. Oneck Drain (ID # 506) in Westhampton, a tributary to Moriches Bay, indicates both real and artifact gains in tidal wetlands (Figure 37). This complex shows intertidal and high marsh areas that have developed in former areas of *Phragmites australis* marsh and uplands as a result of natural or artificial widening, deepening, or stabilization of the channel mouth to Moriches Bay. However, it is also clear that there were areas of intertidal and high marsh present in 1974 that were missed during the original mapping effort.

Table 23: Complexes with Largest Tidal Wetland Loss within Moriches and Shinnecock Bays

Complex (ID #)	1974 IM + HM + FM (acres)	2008 IM + HM + FM (acres)	Δ IM + HM + FM (acres)	Δ IM + HM + FM (%)
Smith Point County Park West (476)	38.7	27.4	-11.3	-29.3
Dune Road Marsh East (529)	44.7	35.0	-9.6	-21.6
William Floyd Estate (471)	166.8	157.6	-9.2	-5.5
Ponquogue Islands (528)	11.5	3.2	-8.3	-72.2
Smith Point County Park East (478)	313.1	305.1	-7.9	-2.5

Table 24: Complexes with Largest Tidal Wetland Loss (%) within Moriches and Shinnecock Bays

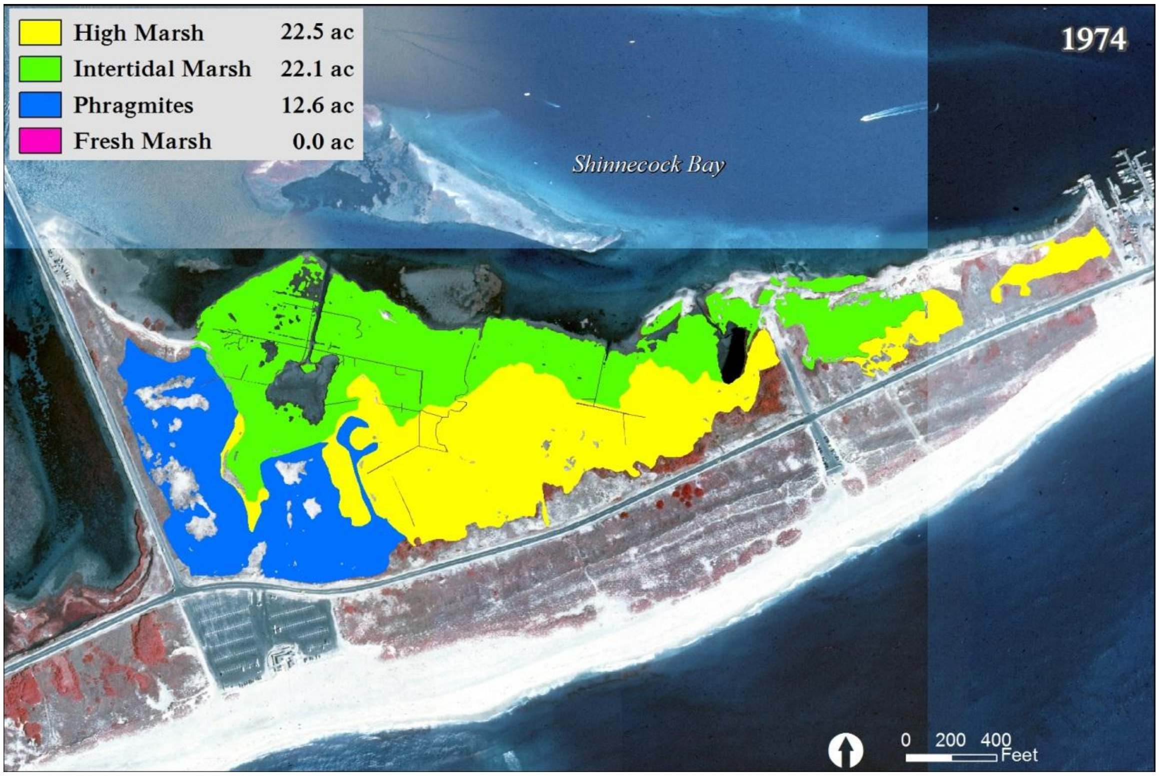
Complex	1974 IM + HM + FM (acres)	2008 IM + HM + FM (acres)	Δ IM + HM + FM (%)	Δ IM + HM + FM (acres)
Ponquogue Islands (528)	11.5	3.2	-72.2	-8.3
Seatuck Creek (493)	12.5	7.8	-37.7	-4.7
Smith Point County Park West (476)	38.7	27.4	-29.3	-11.3
Dune Road Marsh East (529)	44.7	35.0	-21.6	-9.6
Cupsogue Swans Island (482)	16.2	13.6	-16.5	-2.7

Table 25: Complexes with Largest Tidal Wetland Increase within Moriches and Shinnecock Bays

Complex	1974 IM + HM + FM (acres)	2008 IM + HM + FM (acres)	Δ IM + HM + FM (acres)
Oneck Drain (506)	3.9	21.4	17.5
Havens Point (491)	5.7	22.4	16.7
Tuthill Creek (496)	5.2	21.0	15.8
Quogue Canal/Ogden Pond (515)	15.2	23.7	8.5
Mastic Beach (470)	16.1	22.7	6.6

Figure 33: Dune Road Marsh East (Complex ID #529)

[See Page E8, Appendix I for Locator Map]



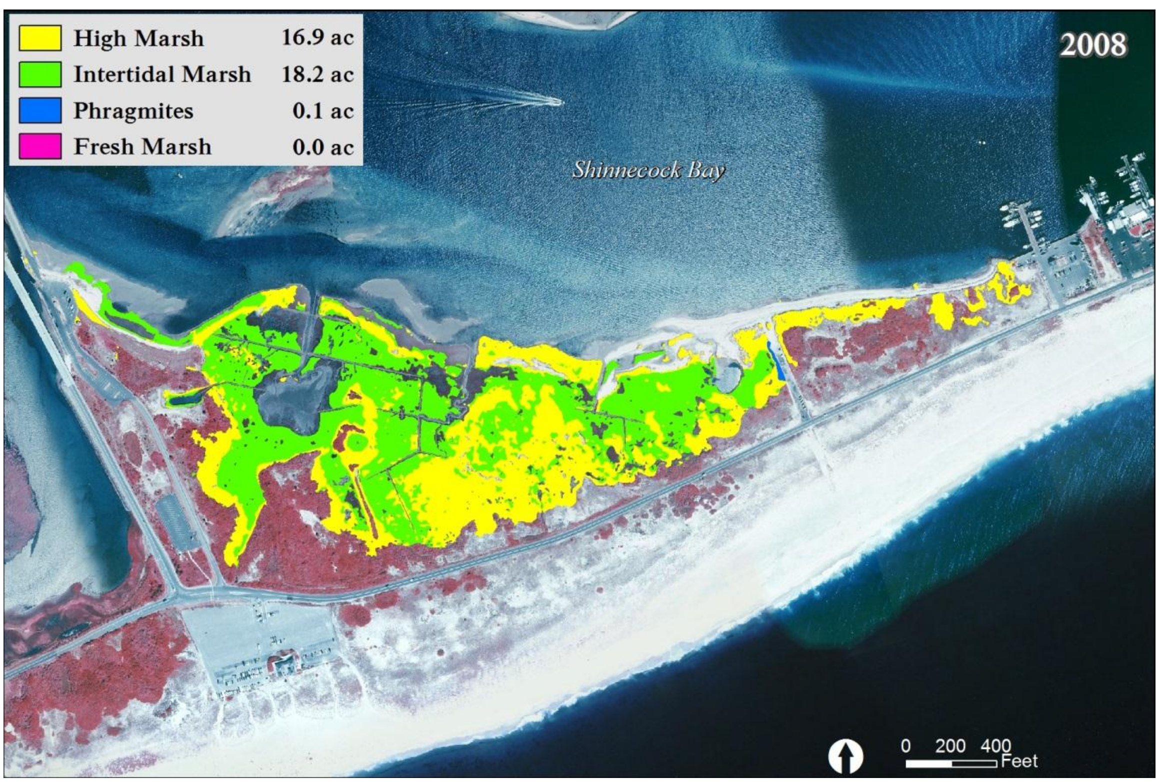


Figure 34: Smith Point County Park West (Complex ID #476)
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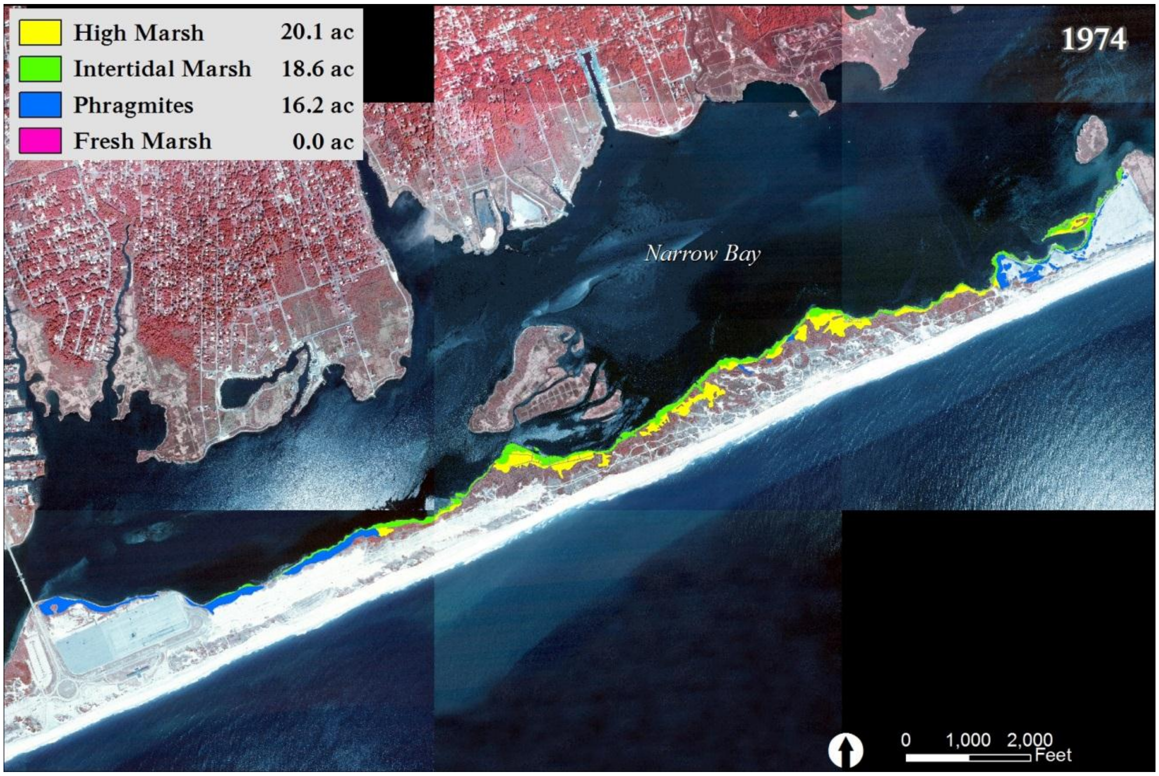


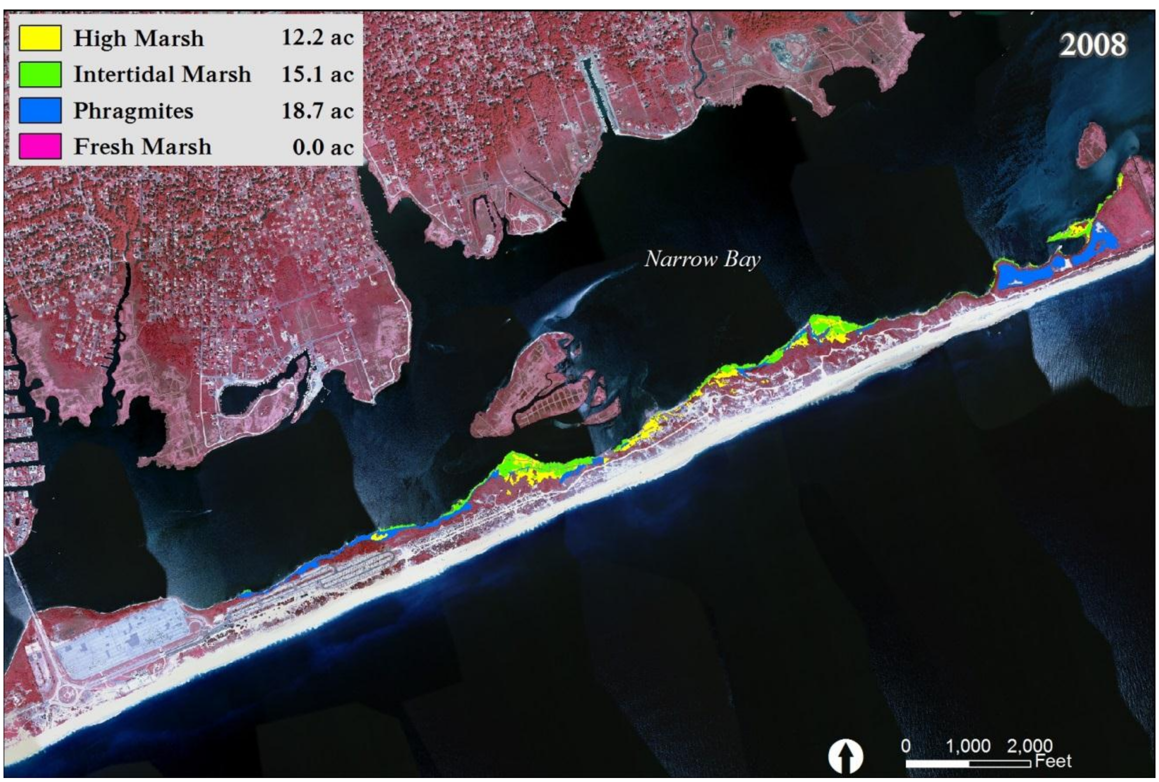
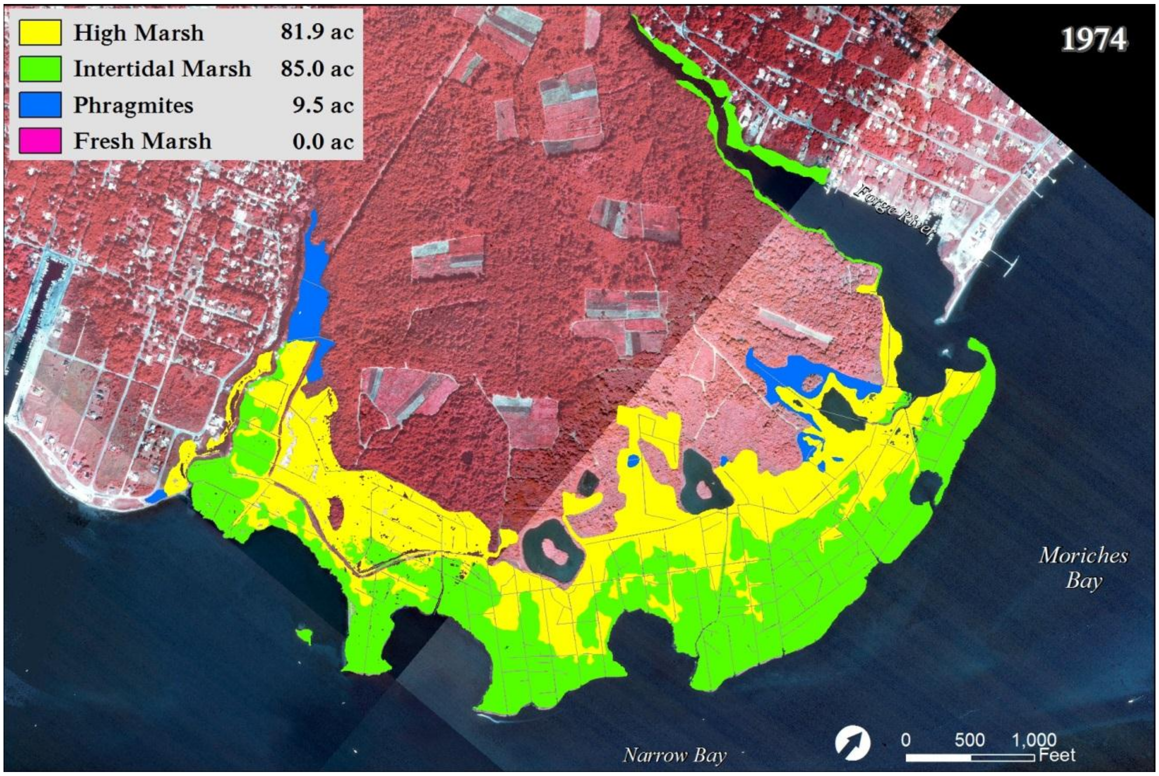


Figure 35: William Floyd Estate (Complex ID #471)
[See Page E6, Appendix I for Locator Map]



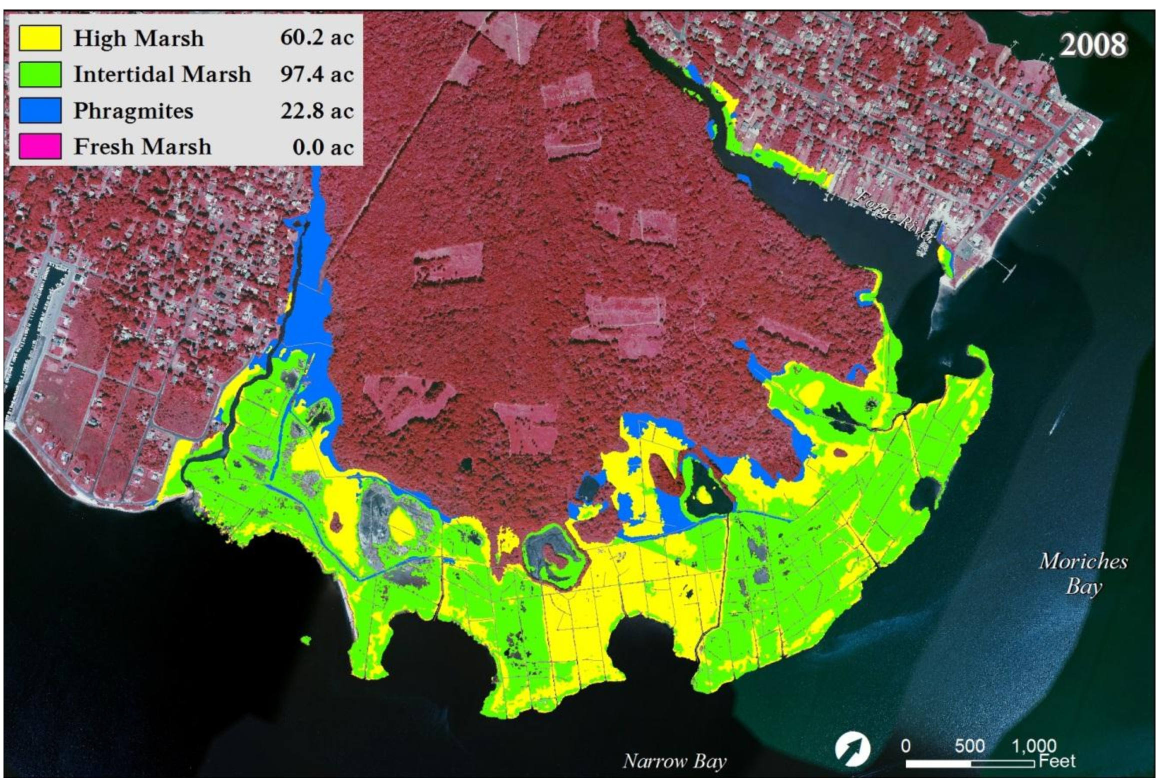
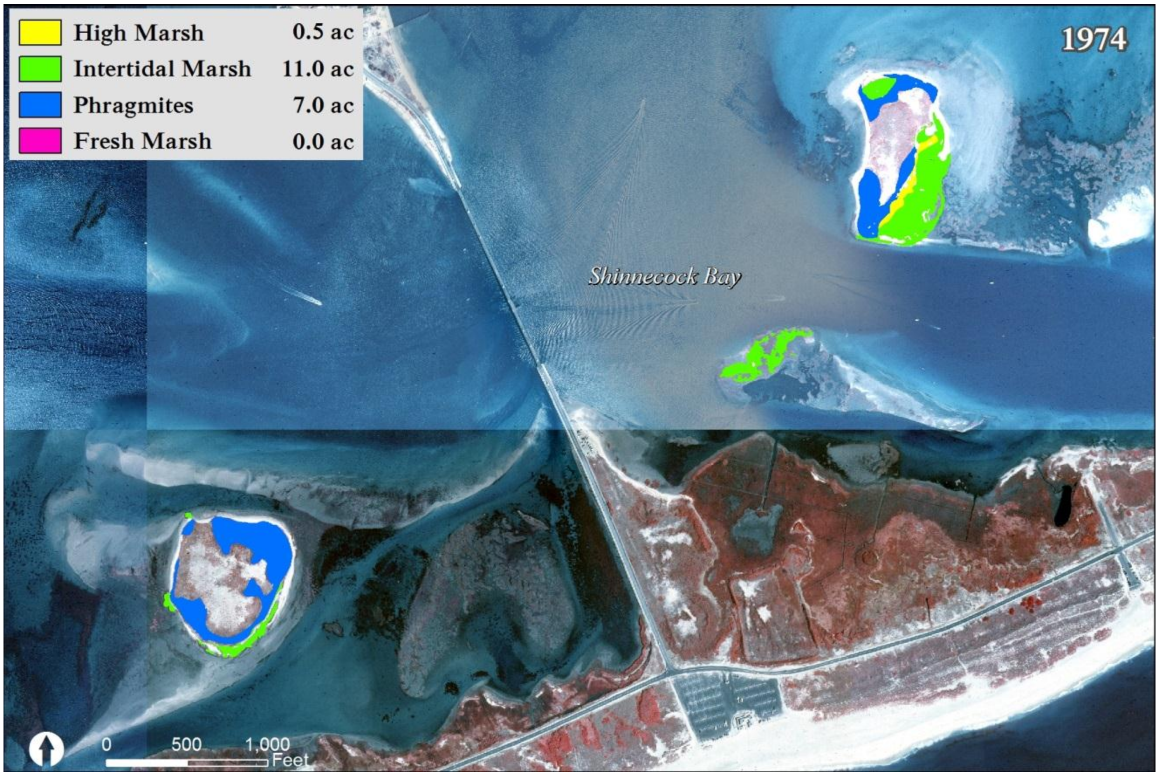


Figure 36: Ponquogue Islands (Complex ID #528)
[See Page E8, Appendix I for Locator Map]



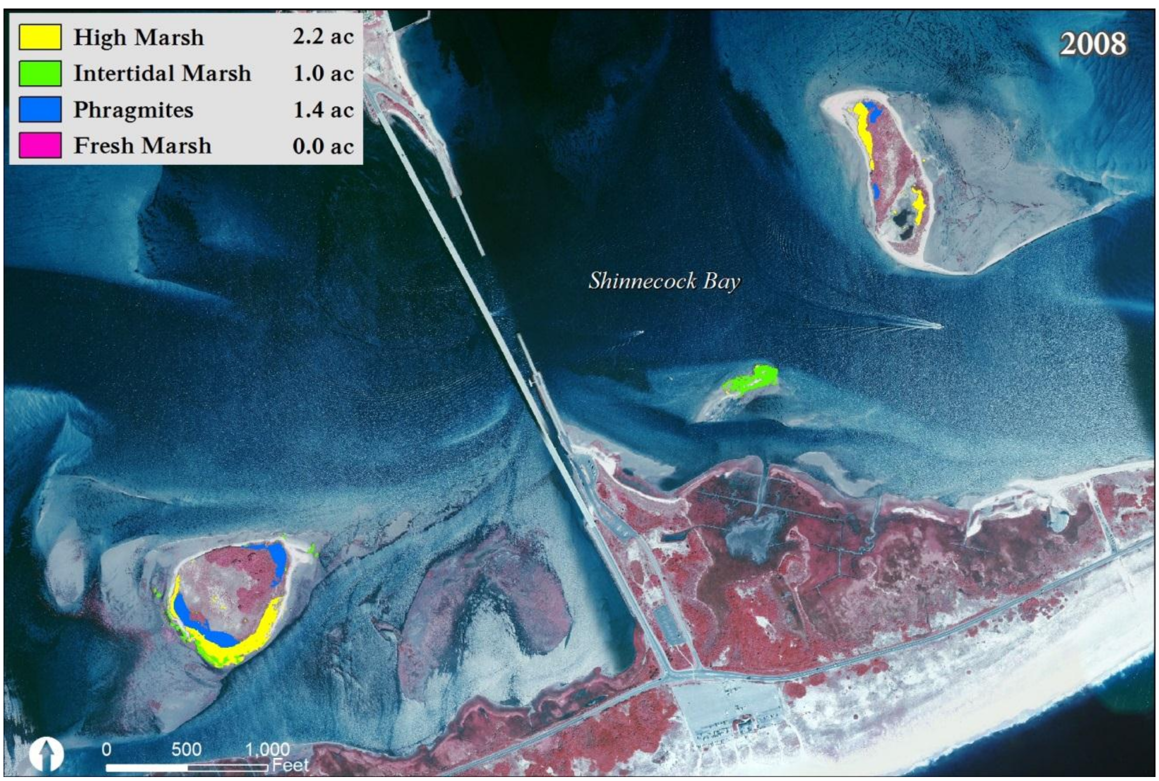
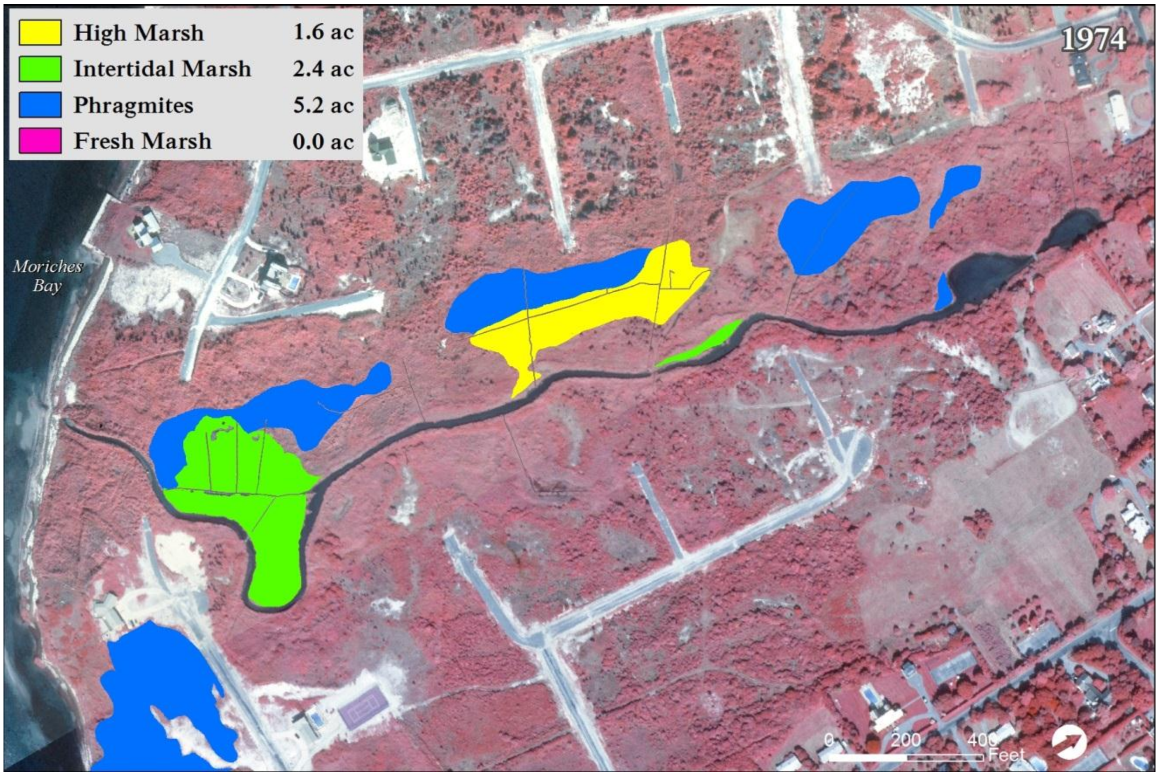
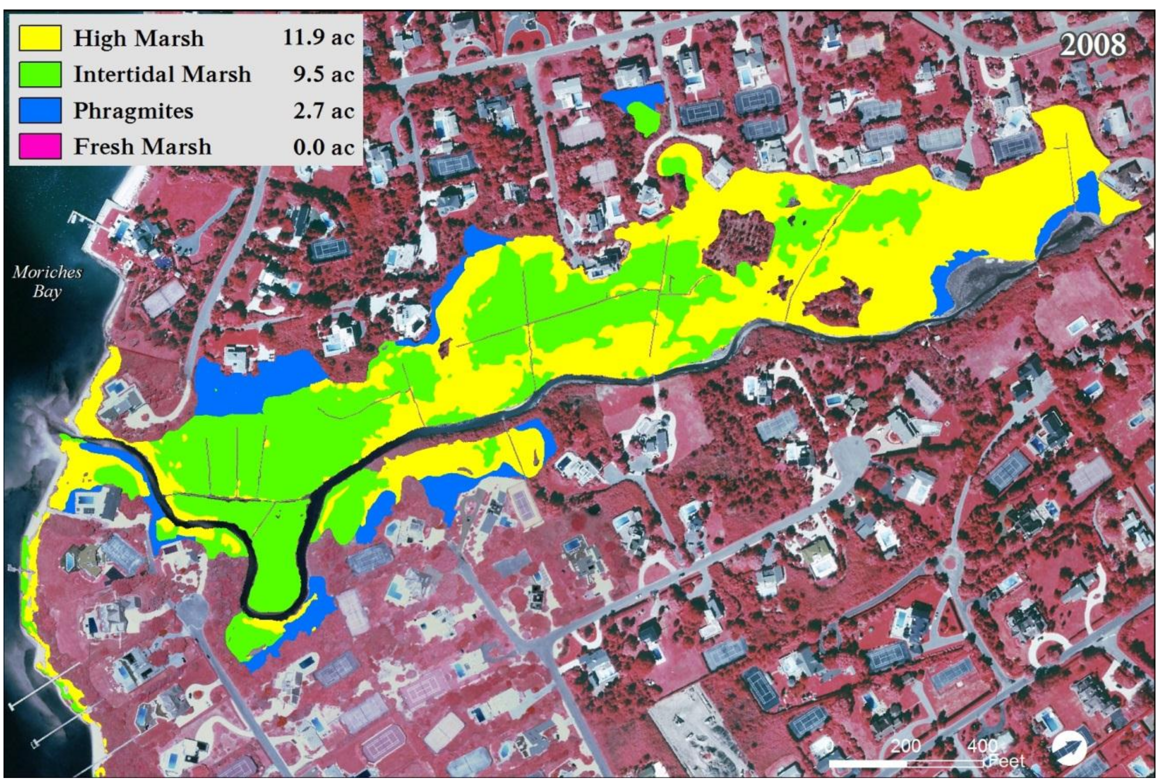


Figure 37: Oneck Drain (Complex ID #506)
[See Page E7, Appendix I for Locator Map]





At-Risk Marsh Complexes

The number of 'At-Risk' marsh complexes and proportion of marsh complexes identified as 'At-Risk' declined eastward within the South Shore Estuary (Table 26). An 'At-Risk' marsh was defined as one in which the loss of vegetated marsh area exceeded 10% from 1974 to 2008. The trends analysis identified 117 'At-Risk' marshes complexes – out of a total of 215 – in the South Shore Estuary. The western Towns typically have more than 70% of wetlands complexes identified as At-Risk compared to the Town of Southampton with only 20.4% of complexes identified as At-Risk. In addition, the 'At-Risk' marshes that have sustained greater than 30% loss in vegetated marsh area tend to be located in the western reaches of the South Shore Estuary with 20 such complexes located in the East Rockaway to Fire Island Inlet Reach, 13 complexes located between Fire Island Inlet and Smith County Park, and only 6 complexes in Moriches and Shinnecock Bays. 'At-Risk' marshes for East Rockaway Inlet to Fire Island Inlet, Fire Island Inlet to Smith Point County Park, and Moriches Bay and Shinnecock Bay are presented in Table 26-Table 29.

Table 26: Frequency of 'At-Risk' in the South Shore Estuary (SSE) by Town

SSE Reach	TOWN	# of At-Risk Marshes	% of At-Risk Marshes
East Rockaway Inlet to Fire Island Inlet	Hempstead	57	91.9
	Oyster Bay	7	77.8
	Babylon	7	33.0
	Islip	3	75.0
	Total	***74***	***77.1***
Fire Island Inlet to Smith Point County Park	Brookhaven	14	60.9
	Islip	14	56.0
	Total	***28***	***57.1***
Moriches and Shinnecock Bays	Brookhaven	7	28.0
	Southampton	10	20.4
	Total	***17***	***23.0***
TOTAL		**117**	**54.4**

Table 27: At-Risk Marshes in the East Rockaway to Fire Island Inlet Reach of the South Shore Estuary by Town

ID #	Wetland Complex	Town	1974 IM+HM+FM (Acres)	2008 IM+HM+FM (Acres)	Change in IM+HM+FM (Acres)	Change in IM+HM+FM (%)
403	Ketcham (Woods) Creek	Babylon	1.3	0.5	-0.7	-59.2%
409	Oak Beach Missing TWL	Babylon	11.9	5.9	-6.0	-50.5%
407	Grass Island	Babylon	5.8	3.8	-2.0	-34.5%
414	Neguntatogue Creek	Babylon	0.3	0.3	0.0	-12.5%
415	Santapogue Creek	Babylon	1.9	1.6	-0.2	-12.4%
397	Elder Island	Babylon	87.1	77.6	-9.5	-10.9%
396	Little Island	Babylon	13.9	12.5	-1.4	-10.1%
	Subtotal		***122.1***	***102.2***	***-19.9***	***-16.3%***
329	Auerbach Canal	Hempstead	0.4	0.0	-0.4	-88.7%
330	Thixton Creek	Hempstead	1.9	0.5	-1.4	-72.2%
332	East Rockaway Channel	Hempstead	6.4	2.4	-4.1	-63.3%
375	Cedar Swamp Creek & Newbridge Creek	Hempstead	3.2	1.4	-1.8	-55.2%
331	Bay County Park	Hempstead	0.9	0.4	-0.5	-52.6%
320	Reynolds Channel	Hempstead	6.8	3.4	-3.4	-50.1%
324	Woodmere Channel & Golf Course	Hempstead	5.0	2.8	-2.2	-44.3%
374	Bellmore Creek	Hempstead	2.4	1.4	-1.0	-41.8%
348	Parsonage Cove	Hempstead	3.2	1.9	-1.3	-40.2%
359	Mill Creek Islands	Hempstead	10.4	6.2	-4.1	-40.0%
340	Island Park East Shoreline	Hempstead	0.9	0.5	-0.4	-39.6%
328	Hewlett Hassock & Nums Marsh	Hempstead	76.1	49.5	-26.6	-34.9%
373	Olivers Island	Hempstead	39.4	25.8	-13.6	-34.5%
334	West Meadow Island	Hempstead	19.2	13.2	-6.1	-31.5%
371	Jones Beach West Tip	Hempstead	29.9	20.5	-9.4	-31.3%
346	Long Meadow & Middle Islands	Hempstead	72.4	50.3	-22.1	-30.6%
345	Ingraham Hassock	Hempstead	41.8	30.0	-11.8	-28.2%
341	East Channel Islands	Hempstead	130.4	93.8	-36.6	-28.1%
351	Seadog Island	Hempstead	136.3	99.2	-37.1	-27.2%
344	Cinder & North Cinder Islands	Hempstead	139.0	101.4	-37.6	-27.0%
367	Cuba, Middle & East Islands	Hempstead	238.5	176.2	-62.3	-26.1%
349	Baldwin Park	Hempstead	22.3	17.0	-5.3	-23.7%
335	North & East Meadow Islands	Hempstead	123.0	95.6	-27.3	-22.2%
352	High Meadow Island	Hempstead	163.3	127.0	-36.3	-22.2%
319	Bannister Creek	Hempstead	93.5	72.8	-20.7	-22.1%
353	Smith Meadow Island	Hempstead	181.6	145.1	-36.5	-20.1%
356	Pine Marsh	Hempstead	204.2	163.7	-40.5	-19.8%
366	Deep Creek Meadow & Snipe Island	Hempstead	194.7	157.2	-37.6	-19.3%
368	Green Island	Hempstead	21.5	17.5	-4.0	-18.8%
363	Big Cow Island	Hempstead	308.4	253.4	-55.0	-17.8%

ID #	Wetland Complex	Town	1974 IM+HM+FM (Acres)	2008 IM+HM+FM (Acres)	Change in IM+HM+FM (Acres)	Change in IM+HM+FM (%)
350	Alder Island/Loop Parkway	Hempstead	210.9	173.8	-37.0	-17.6%
323	Broswere Bay Marsh Islands	Hempstead	116.8	96.3	-20.4	-17.5%
321	Lawrence Upland Fringe Marshes	Hempstead	188.8	157.1	-31.7	-16.8%
343	Parsonage Islands	Hempstead	161.1	135.3	-25.8	-16.0%
339	Garrett Marsh	Hempstead	162.9	137.6	-25.3	-15.5%
362	False Channel Meadow & Neds Meadow	Hempstead	175.2	148.4	-26.8	-15.3%
365	East Cow Island	Hempstead	160.4	136.1	-24.2	-15.1%
364	Jones, Middle & West Cow Islands	Hempstead	374.0	318.8	-55.2	-14.8%
342	Bedell Creek	Hempstead	39.1	33.6	-5.4	-13.9%
383	South Line Island	Hempstead	362.4	312.3	-50.2	-13.8%
357	Petit Marsh	Hempstead	170.6	147.1	-23.5	-13.8%
383	Zachs Bay	Hempstead	148.3	129.3	-19.1	-12.8%
322	Lawrence Marsh	Hempstead	610.8	538.5	-72.3	-11.8%
372	Great Island West	Hempstead	73.7	65.2	-8.5	-11.5%
333	Pearsalls Hassock	Hempstead	56.0	49.6	-6.4	-11.4%
355	Meadow Island	Hempstead	149.7	133.1	-16.6	-11.1%
	Subtotal		***5437.7***	***4442.8***	***-994.9***	***-18.3%***
380	North Line Island	Hempstead / Oyster Bay	180.1	152.6	-27.5	-15.3%
381	Goose Island	Hempstead / Oyster Bay	63.6	47.5	-16.1	-25.4%
	Subtotal		***243.7***	***200.0***	***-43.6***	***-17.9%***
411	Sand Island	Islip	0.0	0.0	0.0	-32.9%
424	East Fire Island	Islip	129.2	99.2	-30.0	-23.2%
412	Saxton Island	Islip	26.3	21.5	-4.8	-18.1%
	Subtotal		***155.5***	***120.7***	***-34.8***	***-22.4%***
390	Carmans River	Oyster Bay	0.2	0.0	-0.2	-95.3%
389	Jones Creek	Oyster Bay	1.0	0.1	-0.8	-85.7%
391	Narrasketuck Creek	Oyster Bay	0.1	0.0	-0.1	-82.1%
388	West, Townsend, Hen, Wanser & Squaw Islands	Oyster Bay	156.4	123.1	-33.3	-21.3%
386	Marsh Islands North of State Boat Channel	Oyster Bay	607.9	504.6	-103.3	-17.0%
	Subtotal		***765.5***	***627.8***	***-137.7***	***-18.0%***

Table 28: At-Risk Marshes in the Fire Island Inlet to Smith Point Reach of the South Shore Estuary by Town

ID #	Wetland Complex	Town	1974 IM+HM+FM (Acres)	2008 IM+HM+FM (Acres)	Change in IM+HM+FM (Acres)	Change in IM+HM+FM (%)
443	Davis Park	Brookhaven	1.3	0.1	-1.3	-94.0%
451	Tuthill Creek	Brookhaven	4.5	0.3	-4.2	-92.5%
444	Watch Hill West	Brookhaven	4.9	0.5	-4.3	-89.2%
442	Barrett Beach to Davis Park	Brookhaven	3.1	0.6	-2.5	-79.9%
453	Swan River	Brookhaven	29.2	14.0	-15.2	-52.1%
454	Mud Creek	Brookhaven	35.6	18.5	-17.1	-48.0%
463	Carmans River Upstream FM	Brookhaven	97.1	61.6	-35.5	-36.6%
456	Hedges Creek	Brookhaven	19.7	14.3	-5.4	-27.4%
450	Corey Creek	Brookhaven	1.2	0.9	-0.3	-26.4%
459	Motts Creek	Brookhaven	15.8	11.7	-4.1	-25.9%
462	Carmans River East	Brookhaven	303.1	251.9	-51.2	-16.9%
461	Fireplace Neck & Carmans River West	Brookhaven	279.5	235.6	-43.9	-15.7%
439	Point O' Woods	Brookhaven	3.6	3.1	-0.6	-15.6%
446	Ridge Island	Brookhaven	34.3	30.3	-4.0	-11.5%
	Subtotal		***832.8***	***643.4***	***-189.4***	***-22.7%***
427	Champlins Creek	Islip	0.8	0.0	-0.8	-95.3%
421	Robert Moses State Park	Islip	23.2	1.6	-21.6	-93.1%
433	Connetquot River	Islip	2.2	0.5	-1.7	-77.6%
438	Brown's River North	Islip	14.9	5.0	-9.8	-66.1%
417	Conklin Point	Islip	0.6	0.4	-0.3	-44.1%
432	Grand Canal & Pickman Wetlands	Islip	29.7	19.9	-9.7	-32.8%
426	Seatuck NWR	Islip	43.3	31.6	-11.6	-26.9%
412	Saxton Island	Islip	31.2	22.9	-8.3	-26.5%
425	Lawrence Creek	Islip	0.1	0.1	0.0	-25.3%
431	Timber Point	Islip	61.3	47.6	-13.7	-22.4%
424	East Fire Island	Islip	130.3	101.5	-38.8	-22.1%
434	Pepperidge State Tidal Wetlands	Islip	96.4	76.0	-20.4	-21.2%
435	Indian Creek	Islip	96.6	79.6	-17.0	-17.6%
437	Brown's River South	Islip	1.4	1.2	-0.2	-13.8%
	Subtotal		***532.0***	***387.9***	***-153.9***	***-28.9%***

Table 29: At-Risk Marshes in the Moriches Bay and Shinnecock Bay Reach of the South Shore Estuary by Town

ID #	Wetland Complex	Town	1974 IM+HM+FM (Acres)	2008 IM+HM+FM (Acres)	Change in IM+HM+FM (Acres)	Change in IM+HM+FM (%)
489	US Coast Guard Station-Moriches	Brookhaven	0.9	0.2	-0.6	-76.1%
487	Radio Point	Brookhaven	1.7	1.0	-0.7	-42.0%
492	Heils Creek	Brookhaven	6.3	4.2	-2.1	-33.4%
476	Smith Point County Park West	Brookhaven	38.7	27.4	-11.3	-29.3%
474	Areskonk Creek	Brookhaven	2.3	1.8	-0.5	-20.4%
479	Made Islands	Brookhaven	6.1	5.1	-1.0	-17.0%
477	Pattersquash Island	Brookhaven	40.2	35.8	-4.4	-11.0%
	Subtotal		***96.1***	***75.3***	***-20.7***	***-21.6%***
528	Ponquogue Islands	Southampton	11.5	3.2	-8.3	-72.2%
520	Davies Creek	Southampton	6.1	3.9	-2.2	-36.0%
539	Halsey Neck Pond	Southampton	6.6	4.3	-2.3	-34.7%
499	Speonk River North	Southampton	9.1	6.5	-2.7	-29.1%
497	Dug Canal	Southampton	0.1	0.1	0.0	-23.8%
495	Fish Creek	Southampton	3.4	2.6	-0.8	-23.4%
529	Dune Road Marsh East	Southampton	44.7	35.0	-9.6	-21.6%
482	Cupsogue Swans Island	Southampton	16.2	13.5	-2.7	-16.5%
486	Terrell River	Southampton	16.1	13.5	-2.6	-16.3%
484	Westhampton Dunes West	Southampton	16.8	14.5	-2.3	-13.6%
	Subtotal		***130.6***	***97.1***	***-33.5***	***-25.6%***

Long Island Sound Estuary

The portions of the Long Island Sound Estuary in the study area were divided into 152 marsh complexes varying in vegetated area from 0.1 to 235 acres. Intertidal and high marsh habitat decreased by 24.4% and 17.3%, respectively, from 1974 to 2005 (see Table 30). In total, marsh habitat decreased by an estimated 654.3 acres (see Table 31). *Phragmites australis* increased by 33.6%, or 106.6 acres. *Phragmites australis* displaced a portion of the former high marsh habitat such that there was only a 17.1% reduction in overall vegetated area despite the loss of 22.6% of native intertidal, high, and coastal fresh marsh habitat.

Table 30: Tidal Wetland Area Change (1974-2005) in Long Island Sound by Class

Wetland Type	1974 Wetland Area (acres)	2005 Wetland Area (acres)	Change (%)
Intertidal Marsh	1,920.6	1,451.7	-24.4
High Marsh	950.2	785.9	-17.3
Fresh Marsh	21.0	0.0	-100.0
Marsh Subtotal	2,891.8	2,237.6	-22.6
Phragmites australis	317.1	423.7	+33.6
Vegetated Area Total	3,209.0	2,661.2	-17.1

Table 31: Tidal Wetland Area Change in Long Island Sound by Town/County

Municipality	1974 IM + HM + FM (acres)	2005 IM + HM + FM (acres)	Δ IM + HM + FM (acres)	Δ IM + HM + FM (%)
Bronx (Bx)	272.0	194.1	-77.8	-28.6
Brookhaven (Bk)	403.1	336.1	-67.0	-16.6
Huntington (Hu)	683.9	520.3	-163.6	-23.9
North Hempstead (NH)	145.0	100.5	-44.5	-30.7
Oyster Bay (OB)	369.1	310.7	-58.4	-15.8
Queens (Qu)	80.7	68.8	-11.9	-14.8
Riverhead (Ri)	162.7	126.3	-36.4	-22.4
Smithtown (Sm)	506.7	373.9	-132.8	-26.2
Southold (So)	79.0	85.9	+7.0	+8.8
Westchester (We)	189.6	120.9	-68.7	-36.2
Total	2,891.8	2,237.6	-654.3	-22.6

Table 32: Complexes with Largest Tidal Wetland Area Loss in Long Island Sound

Complex (ID #)	1974 IM + HM + FM (acres)	2005 IM + HM + FM (acres)	Δ IM + HM + FM (acres)
Porpoise Channel Islands (105)	106.8	49.2	-57.6
Hutchinson River (550)	122.4	76.1	-46.4
Crab Meadow (222)	242.0	208.3	-33.7
Mount Sinai Harbor Islands (90)	69.8	38.0	-31.8
Marshland Conservancy & Blind Brook (313)	72.8	47.4	-25.4
Lloyd Harbor (234)	123.6	103.0	-20.6
Lloyd Point Wetlands (236)	96.2	76.0	-20.3
Inner Hempstead Harbor West (267)	50.5	28.8	-22.2
Wading River Marsh (87)	145.6	126.3	-19.3
Baiting Hollow Marsh (85)	17.2	0.0	-17.2

Portions of the Long Island Sound Estuary included in this study were the Bronx and Queens in New York City; New Rochelle, Mamaroneck, and Rye in Westchester County; and several Towns in Nassau and Suffolk Counties. A large majority, i.e., about 82%, of the marsh habitat is located in Nassau and Suffolk Counties. Approximately 12% of the marshes are situated in New York City, with the remainder (6%) located in Westchester County, primarily in the Town and City of Rye.

Table 33: Complexes with Highest Percent Loss of Tidal Wetlands in Long Island Sound

Complex (ID #)	1974 IM + HM + FM (acres)	2005 IM + HM + FM (acres)	Δ IM + HM + FM (%)
Baiting Hollow Marsh (85)	17.2	0.0	-100.0
Sheets Creek Channel (275)	9.8	1.1	-88.7
Northport Harbor- Bird Island (225)	16.8	3.5	-79.3
LIS- Milton Point to Rye Beach (314)	14.4	3.6	-85.1
Northport Harbor (226)	19.3	5.4	-71.9
West Pond (261)	20.8	8.5	-59.0
Cold Spring Harbor- East Shoreline (240)	11.1	4.7	-57.6
Porpoise Channel Islands (105)	106.7	49.2	-53.9
Huntington Harbor (233)	22.3	10.4	-53.4
Mitchell Creek (282)	13.3	6.7	-49.2

The largest losses in marsh area from 1974 to 2005 occurred in the Towns of Huntington (163.6 acres lost), Smithtown (132.8 acres lost), Brookhaven (67.0 acres lost), and North Hempstead (44.5 acres lost); in addition, the Bronx lost an estimated 77.8 acres of marsh. There is a general trend towards western municipalities exhibiting greater losses of native tidal wetlands communities (Table 31). However, there was no statistically significant relationship between percent loss of native tidal wetlands and longitude position within the Long Island Sound estuary ($R^2 = 0.02$), as many complexes in the eastern portion of the estuary also exhibited high rates of tidal wetlands loss and vice versa.

Cumulatively, the north shore of Long Island and portions of Queens, the Bronx, and Westchester included in this study lost 654.3 acres of native tidal wetlands (22.6% of total marsh area) between 1974 and 2005 averaging 21.1 acres of marsh loss annually.

Portions of the Long Island Sound Estuary included in this study were the Bronx and Queens in New York City; New Rochelle, Mamaroneck, and Rye in Westchester County; and several Towns in Nassau and Suffolk Counties. A large majority, i.e., about 82%, of the marsh habitat is located in Nassau and Suffolk Counties. Approximately 12% of the marshes are situated in New York City, with the remainder (6%) located in Westchester County, primarily in the Town and City of Rye.Table 33 provides summaries of the marsh complexes that incurred the largest losses in marsh area. The ten wetland complexes listed in Table 32 account for almost 45% of the marsh habitat lost in the estuary from 1974 to 2005. In addition, approximately 75% of the marsh loss occurred in only 27 out of the 152 marsh complexes. Approximately 40% of these 30 complexes were more than 40 acres in area, while the remainder were typically greater than 25 acres in area. Small marsh complexes can also exhibit high rates of marsh loss. However, due to their small size, large percentages of area loss (or gain) in small complexes have much less influence on estuary-wide trends in tidal wetland area and, accordingly, estuary or regional trends in marsh area change are determined by trends in the larger wetland complexes. The spatial distribution of the variation in marsh change percentages between 1974 and 2005 is shown in Figure 38.

Figure 38: Long Island Sound Wetland Complexes by Percent Change in Vegetated Marsh Area (1974-2005)

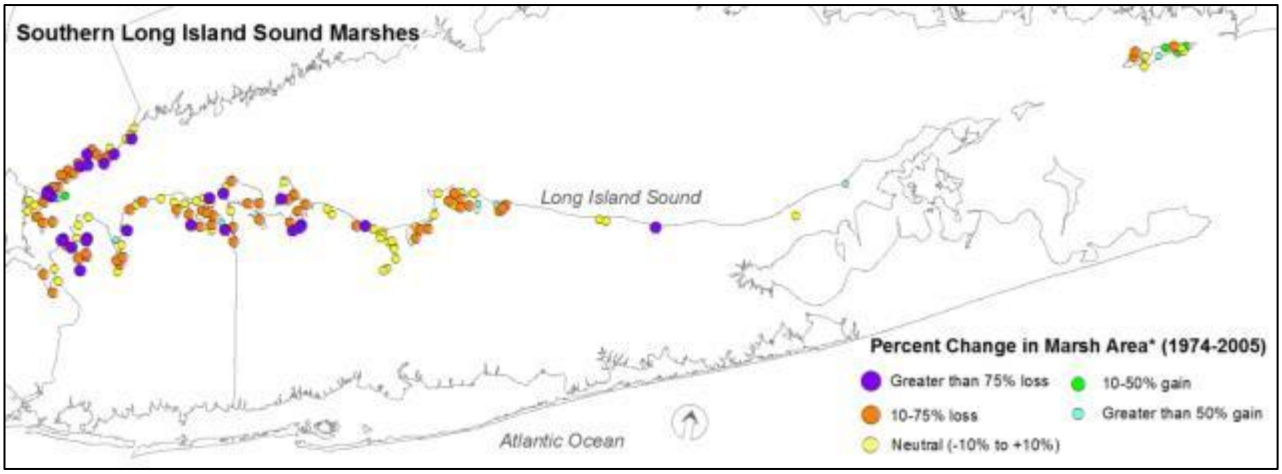


Figure 39 through Figure 44 depict the native marsh and *Phragmites* areas for six of the complexes identified in Table 32 as having the greatest marsh loss by area: Stony Brook Harbor (ID # 105), Crab Meadow (ID # 222), Mount Sinai Harbor Islands (ID # 90), Lloyd Point Wetlands (ID # 236), Inner Hempstead Harbor West (ID # 267) and Baiting Hollow Marsh (ID # 85) complexes. Figure 44 through Figure 46 depict the marsh and *Phragmites australis* areas for the three marsh complexes with the greatest percentage of marsh loss: Baiting Hollow Marsh (ID # 85), Sheets Creek Channel (ID # 275), and the Long Island Sound shoreline between Milton Point and Rye Beach (ID # 314). The wetland complexes listed in Table 32 and shown in Figure 39 through Figure 46 exhibit many of the characteristic biological and geomorphological associated with marsh loss described for the South Shore Estuary.

The wetland complexes of the Long Island Sound exhibit a substantial loss of intertidal marsh habitats. Losses are observed in complexes both with large intertidal marsh islands, such as Stony Brook Harbor (Figure 39) and Mount Sinai Harbor (Figure 41), and marshes along embayment shorelines, such as Hempstead Harbor (Figure 43). As shown in Table 33, there are many large complexes (greater than 10 acres in 1974) that have lost more than 50% of their marsh area in the short period between 1974 and 2005 with some complexes exhibiting more 80% to 100% loss of intertidal marsh habitat. Table 10 indicates that eleven of the fifteen wetland complexes with the greatest percentage loss of intertidal marshes are located within the Long Island Sound estuary. Similar to the western portion of the South Shore estuary, the Long Island Sound estuary had a lower ratio of high marsh vegetation (32.8%) to total native marsh area in 1974 compared to the Peconic Estuary (49.8%) and central and eastern portions of the South Shore estuary (41.2-53.3%) (Table 5). Thus, in the Long Island Sound conversion of intertidal marsh to panne and mudflat (often due the recession of the seaward edge of the intertidal marsh) was not offset by conversions of high marsh habitats into intertidal marsh. Further investigation is necessary to determine which of the interacting causes of marsh loss related the nutrient loading, sea level rise, sediment budget perturbations, and recreational uses contribute most to the rapid loss of intertidal marsh habitats in the Long Island Sound. In addition, pilot projects to restore lost marshes, decrease the deterioration rates in remaining marshes, or establish new marsh areas should be undertaken in these embayments.

The limited complexes in the Long Island Sound with large high marsh components, such as Crab Meadow (ID # 222), Wading River Marsh (ID # 87), Lloyd Harbor (ID # 234), Hutchinson River (ID # 549 and 550), and West Meadow Creek (ID # 104) exhibit marsh drowning and conversion to intertidal marsh similar to the central portions of the South Shore Estuary and the Peconic Estuary. The high marsh to intertidal marsh conversion in Crab Meadow (ID # 222) and Lloyd Point (ID # 236) is shown in Figure 40 and Figure 42, respectively. These wetland complexes comprised approximately 50% of the high marshes present in the Long Island Sound in 1974 (487.1 of 950.2 acres) and lost collectively 75.4% of high marsh between 1974 and 2005.

Phragmites australis expansion has contributed to the decline in high marsh and total native marsh area in the Long Island Sound. At Baiting Hollow marsh (ID # 85, Figure 44), the complete loss of native marsh habitat is due entirely to *Phragmites australis* expansion and significant *Phragmites australis* expansion has occurred in many of the complexes with large high marsh components, including Crab Meadow and Wading River marshes, and complexes with freshwater inputs, such as the Nissequogue River (ID # 207-220). Table 34 lists the ten Long Island Sound marsh complexes that have sustained the greatest amount of *Phragmites australis* expansion. Collectively, *Phragmites australis* in these complexes accounts for over half (or 59%) of the 155.0 acres of *Phragmites australis* expansion in the southern portion of the Long Island Sound Estuary.

Table 34: Complexes with Largest *Phragmites australis* Expansion in Long Island Sound

Complex (ID #)	1974 *Phragmites* (acres)	2005 *Phragmites* (acres)	Δ *Phragmites* (acres)
Wading River Marsh (87)	7.7	25.6	17.9
Crab Meadow (222)	6.2	19.9	13.7
Nissequogue Downstream Coastal FM (216)	16.2	29.0	12.8
Hutchinson River (550)	5.3	16.6	11.3
Baiting Hollow Marsh (85)	7.1	16.0	8.9
Conscience Bay (101)	0	6	6.0
Stony Brook Harbor South (108)	0.5	6.3	5.8
Crab Meadow Coastal FM (221)	0	5.6	5.6
Marshland Conservancy & Blind Brook (313)	6.5	12.1	5.6
Inner Hempstead Harbor West (267)	5.5	10.7	5.2

Review of the patterns of marsh gain and loss in the Long Island Sound suggests the importance of long-term changes in inlet morphology, and resulting perturbations to amplitude of the tidal prism and the duration of ebb and flood tides, may be responsible for changes in marsh composition in some complexes. For example, the inlet for the Baiting Hollow Marsh (ID # 85) has completely shoaled between 1974 and 2005, preventing ebb tides, inundating the former marsh area leading to formation of a large marsh pond, and presumably decreasing salinity within the marsh contributing to the expansion of *Phragmites australis*. In contrast, the inlet for East Creek in Sands Point (ID # 303) appears to have remained relatively open between 1974 and 2005 and *Spartina alterniflora* has expanded into mudflat areas since 1974 (Figure 47). The role of inlet dynamics in maintaining tidal wetlands in the smaller embayments on the North Shore of Long Island has obvious management implications for several complexes experiencing moderate or large marsh loss rates such as Flax Pond (ID # 103), West Pond (ID # 261), and Lloyd Point Marsh (ID # 236).

Table 35: Complexes with Largest Gain in Tidal Wetland Area in Long Island Sound

Complex (ID #)	1974 IM + HM + FM (acres)	2005 IM + HM + FM (acres)	Δ IM + HM + FM (acres)
Prospect Point/East Creek (272)	21.9	31.6	+9.7
Centre Island Marsh (251)	32.5	34.5	+2.1
Sagamore Hill Marsh (243)	3.7	5.7	+2.0
Goldsmith Inlet (83)	2.9	4.8	+1.9

Four of the wetland complexes that have gained marsh habitat from 1975 through 2005 are listed in Table 35. These include Prospect Point/East Creek and Sagamore Hill Marsh which are shown in Figure 47 and Figure 48. Marsh area gains accounted for 33.7 acres of new habitat, but these are minimal gains compared with the net loss 654.5 acres of native marshes from 1974 to 2005. The calculated 9.7 acres of native marsh gained at Prospect Point may overestimate the positive trend in marsh area as 1) native high marsh (and *Phragmites australis*) has colonized an area in the southeast corner of the marsh that was cleared and filled in the 1974 imagery and 2) the 1974 imagery appears to show standing water above some areas of intertidal marsh in 1974 and extensive waterlogging. Despite these difficulties with comparison of the 1974 and 2005 images, the Prospect Point/East Creek Marsh also exhibits actual evidence of natural marsh gain and improved marsh health including 1) conversion of intertidal marsh to high marsh, 2) decrease in abundance of stressed intertidal marsh vegetation, 3) dense intertidal marsh development in sparsely vegetated areas, and 4) apparent narrowing of marsh channels. Favorable inlet geomorphology and tidal exchange are likely responsible for the gains in marsh area and health at Prospect Point or certainly the absence of marsh loss typically observed in Long Island Sound wetland complexes. At Sagamore Hill, high marsh vegetation appears to have migrated landward and colonized sandy, open beach areas that were sparsely vegetated in 1974.

Table 36 summarizes the At-Risk marshes in Long Island Sound Estuary by town. An 'At-Risk' marsh was defined as one for which the loss of vegetated marsh area exceeded 10% from 1974 to 2005. The trends analysis identified 100 'At-Risk' marsh complexes – out of a total of 152 – in the Long Island Sound Estuary.

Table 36: At-Risk Marshes in the Long Island Sound Estuary by Town

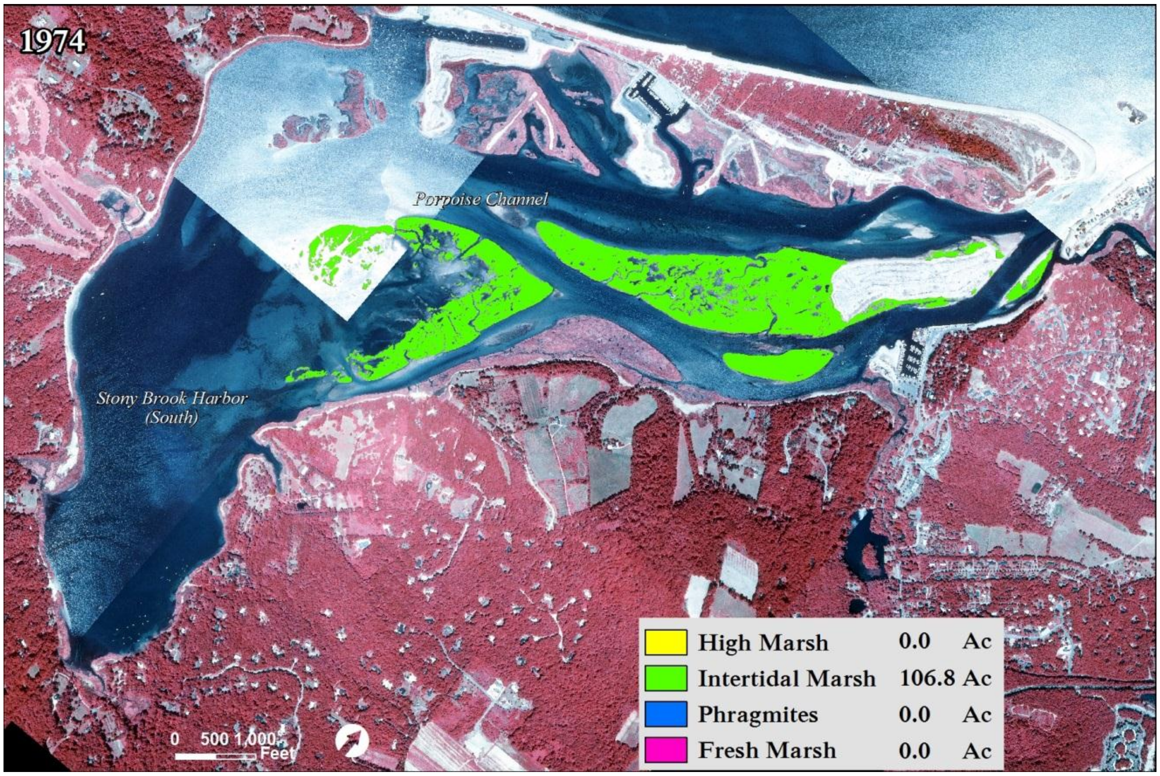
ID #	Wetland Complex	Town	1974 IM+HM +FM (Acres)	2005 IM + HM + FM (Acres)	Change in IM+HM+FM (Acres)	Change in IM+HM+FM (%)
553	Hart Island	Bronx	4.5	1.8	-2.8	-61.4
552	City Island	Bronx	5.4	2.3	-3.1	-57.0
550	Hutchinson River	Bronx	122.4	76.1	-46.4	-37.9
551	Pelham Bay East Shore	Bronx	9.3	5.8	-3.4	-36.9
547	Hunter Island	Bronx	37.2	25.2	-12.1	-32.4
546	Pelham Bay Park	Bronx	31.7	26.5	-5.3	-16.6
	Subtotal		***210.7***	***137.6***	***-73.0***	***-34.7***
90	Mount Sinai Harbor Islands	Brookhaven	69.8	38.0	-31.8	-45.5
89	Mount Sinai Harbor North	Brookhaven	20.3	13.8	-6.5	-32.2
91	Mount Sinai Harbor South	Brookhaven	48.4	32.9	-15.6	-32.1
99	The Narrows	Brookhaven	6.3	4.5	-1.8	-28.0
95	Port Jefferson Harbor Poquott	Brookhaven	2.9	2.1	-0.8	-27.0
96	Setauket Harbor	Brookhaven	19.7	17.4	-2.3	-11.7
	Subtotal		***228.8***	***165.2***	***-63.6***	***-27.8***
231	Price Bend & Shoreline IM	Huntington	0.9	0.0	-0.9	-100.0
238	Whitewood Point	Huntington	0.2	0.0	-0.2	-100.0
228	Centerport Mill Pond	Huntington	1.7	0.1	-1.6	-94.7
221	Crab Meadow Coastal FM	Huntington	6.4	0.5	-5.9	-92.2
225	Northport Harbor Bird Island	Huntington	16.8	3.5	-13.3	-79.3
226	Northport Harbor	Huntington	19.3	5.4	-13.9	-71.9
223	Northport Bay Shoreline	Huntington	8.6	3.0	-5.5	-64.3
224	Asharoken Marsh	Huntington	1.7	0.6	-1.1	-63.0
240	Cold Spring Harbor East Shoreline	Huntington	11.1	4.7	-6.4	-57.6
235	Huntington Bay East Beach	Huntington	4.0	1.8	-2.3	-56.2
233	Huntington Harbor	Huntington	22.3	10.4	-11.9	-53.4
230	Winkle Point	Huntington	5.2	3.1	-2.1	-41.2
227	Centerport Harbor	Huntington	11.2	6.8	-4.3	-38.8
236	Lloyd Point Wetlands	Huntington	96.2	76.0	-20.3	-21.1
229	Duck Island Harbor	Huntington	54.3	44.3	-10.0	-18.4
234	Lloyd Harbor	Huntington	123.6	103.0	-20.6	-16.7
239	Lloyd Harbor Park	Huntington	7.3	6.1	-1.2	-15.9
222	Crab Meadow	Huntington	242.0	208.3	-33.7	-13.9
237	Spring Bay Wetlands	Huntington	11.3	10.1	-1.1	-10.0
	Subtotal		***644.0***	***487.7***	***-156.2***	***-24.3***
241	Cold Spring Harbor Inner Harbor	Huntington/Oyster Bay	15.2	9.3	-5.9	-38.6
298	Premium Point	Larchmont	0.7	0.5	-0.2	-31.0
301	LI Sound Preyer Ln to Umbrella Pt	Larchmont	1.9	1.5	-0.5	-23.4
300	Premium River	Larchmont	9.9	8.1	-1.8	-18.4
	Subtotal		***12.5***	***10.1***	***-2.4***	***-19.2***

ID #	Wetland Complex	Town	1974 IM+HM+ FM (Acres)	2005 IM + HM + FM (Acres)	Change in IM+HM + FM (Acres)	Change in IM+HM+FM (%)
302	Larchmont Harbor	Larchmont/Mamaroneck	7.2	1.3	-5.8	-81.5
303	East Creek	Larchmont/Mamaroneck	5.6	4.8	-0.8	-14.8
		Subtotal	***12.8***	***6.1***	***-6.7***	***-52.3***
305	LI Sound Edgewater Pt to Orient Pt	Mamaroneck	4.2	0.0	-4.2	-99.3
306	Mamaroneck Harbor East & West Basins	Mamaroneck/Rye	3.4	0.8	-2.6	-77.6
293	Lower New Rochelle Harbor	New Rochelle	0.2	0.0	-0.2	-87.5
291	Goose Island	New Rochelle	0.6	0.1	-0.5	-82.1
294	Inner Neptune Island	New Rochelle	0.8	0.1	-0.7	-79.1
295	New Rochelle Harbor & Titus Mill Pond	New Rochelle	4.4	1.3	-3.1	-70.2
296	Davenport Island Shoreline	New Rochelle	2.5	1.2	-1.3	-50.3
297	Echo Bay	New Rochelle	1.7	0.9	-0.8	-46.6
292	Glen Island	New Rochelle	0.6	0.4	-0.2	-34.8
		Subtotal	***10.7***	***4.1***	***-6.5***	***-61.2***
284	Gatsby Lane FC Wetland	North Hempstead	0.4	0.0	-0.4	-100.0
276	Toms Point	North Hempstead	2.0	0.1	-2.0	-97.2
283	Manhasset Bay NW Shoreline	North Hempstead	1.5	0.1	-1.4	-91.8
279	Inner Manhasset Harbor	North Hempstead	3.8	0.3	-3.4	-91.0
275	Sheets Creek Channel	North Hempstead	9.8	1.1	-8.7	-88.3
281	Kings Point Lagoon & Twin Ponds	North Hempstead	0.5	0.1	-0.4	-87.4
277	Manhasset Bay East Shoreline	North Hempstead	8.1	3.6	-4.5	-55.8
282	Mitchell Creek	North Hempstead	13.3	6.7	-6.5	-49.2
278	Leeds Pond	North Hempstead	6.2	3.3	-2.9	-47.5
280	Manhasset Bay West Shoreline	North Hempstead	6.6	3.5	-3.0	-46.9
267	Inner Hempstead Harbor West	North Hempstead	48.4	28.6	-19.8	-40.9
274	Plum Point	North Hempstead	5.8	4.9	-1.0	-16.5
		Subtotal	***106.4***	***52.2***	***-54.2***	***-50.9***
285	Little Neck Bay West Shoreline	Queens	6.3	2.0	-4.3	-67.8
287	Alley Pond	Queens	44.2	39.5	-4.7	-10.7
286	Udalls Cove	Queens	30.2	27.2	-2.9	-9.7
		Subtotal	***80.7***	***68.7***	***-12.0***	***-14.9***
85	Baiting Hollow Marsh	Riverhead	17.2	0.0	-17.2	-100.0
87	Wading River Marsh	Riverhead	145.6	126.3	-19.3	-13.2
		Subtotal	***162.8***	***126.3***	***-36.5***	***-22.4***
248	Mill Creek	Oyster Bay	0.1	0.0	-0.1	-100.0
252	Centre Island NE Shoreline	Oyster Bay	2.4	0.0	-2.4	-98.4
242	Cold Spring Harbor Wst. Shoreline	Oyster Bay	3.9	0.9	-3.0	-76.4
264	Glen Cove Creek	Oyster Bay	2.4	0.6	-1.9	-75.8
270	Motts Creek	Oyster Bay	2.3	0.8	-1.5	-64.2
261	West Pond	Oyster Bay	20.8	8.5	-12.3	-59.0
262	Cobble Court Marsh	Oyster Bay	2.8	1.3	-1.5	-52.3
269	Inner Hempstead Harbor East	Oyster Bay	12.7	7.8	-4.9	-38.7
260	Desoris Pond	Oyster Bay	2.1	1.3	-0.8	-36.6

ID #	Wetland Complex	Town	1974 IM+HM+FM (Acres)	2005 IM + HM+FM (Acres)	Change in IM+HM+FM (Acres)	Change in IM+HM+FM (%)
249	Mill Neck East Shoreline	Oyster Bay	15.7	10.3	-5.4	-34.4
250	Centre Island East Shoreline	Oyster Bay	13.0	8.7	-4.3	-33.1
253	Centre Island West Shoreline	Oyster Bay	12.3	9.6	-2.7	-21.9
245	Cove Neck West Shoreline	Oyster Bay	6.8	5.6	-1.2	-18.2
259	Frost Creek	Oyster Bay	56.2	46.1	-10.1	-18.0
257	Beaver Creek	Oyster Bay	29.1	24.3	-4.7	-16.3
247	Oyster Bay South Shoreline	Oyster Bay	7.6	6.4	-1.1	-14.8
		Subtotal	***190.1***	***132.4***	***-57.7***	***-30.4***
311	Scotch Cap Islands	Rye	1.5	0.2	-1.3	-85.3
314	LI Sound Milton Pt to Rye Beach	Rye	14.4	3.6	-10.8	-75.1
317	Manursing Island Shoreline	Rye	2.6	0.7	-1.9	-73.6
312	Milton Harbor	Rye	2.6	0.9	-1.5	-62.9
310	Hen Island	Rye	19.5	12.5	-7.0	-35.8
313	Marshland Conservancy & Blind Brook	Rye	72.3	47.4	-25.4	-34.9
307	East Basin Creek	Rye	3.9	3.3	-0.6	-15.5
		Subtotal	***144.9***	***98.1***	***-46.9***	***-32.3***
219	Nissequogue Sunken Meadow Moat	Smithtown	2.8	0.0	-2.8	-100.0
220	Nissequogue Upper Sunken Meadow Creek	Smithtown	8.7	1.7	-7.0	-80.8
105	Porpoise Channel Islands	Smithtown	106.7	49.2	-57.5	-53.9
107	Stony Brook Creek	Smithtown	5.6	2.8	-2.9	-49.5
108	Stony Brook Harbor South	Smithtown	52.1	37.7	-14.4	-27.7
214	Nissequogue Smithtown Landing Golf Course	Smithtown	4.1	3.0	-1.1	-27.3
207	Nissequogue Mouth of Sunken Meadow Creek	Smithtown	60.7	44.5	-16.2	-26.6
209	Short Beach	Smithtown	22.6	18.3	-4.3	-19.1
212	Nissequogue Landing County Park	Smithtown	15.4	12.5	-2.9	-18.8
215	Nissequogue East	Smithtown	86.5	71.2	-15.3	-17.7
216	Nissequogue Downstream Coastal FM	Smithtown	9.3	7.6	-1.6	-17.6
210	Nissequogue IM Island	Smithtown	20.3	16.8	-3.5	-17.3
211	Nissequogue Riveria Drive Shoreline	Smithtown	15.3	12.8	-2.5	-16.1
		Subtotal	***410.2***	***278.2***	***-132.0***	***-32.2***
20	Fisher's Island Hungry Pt to Brooks Pt	Southold	1.1	0.8	-0.4	-31.4
26	Fisher's Island Hay Harbor	Southold	2.2	1.6	-0.6	-27.7
24	Fisher's Island Crescent Ave	Southold	0.9	0.8	-0.1	-11.6
		Subtotal	***4.2***	***3.2***	***-1.1***	***-26.2***

Figure 39: Porpoise Channel Islands & Stony Brook Harbor South (Complex ID #105 and ID #108)

[See Page D4, Appendix I for Locator Map]



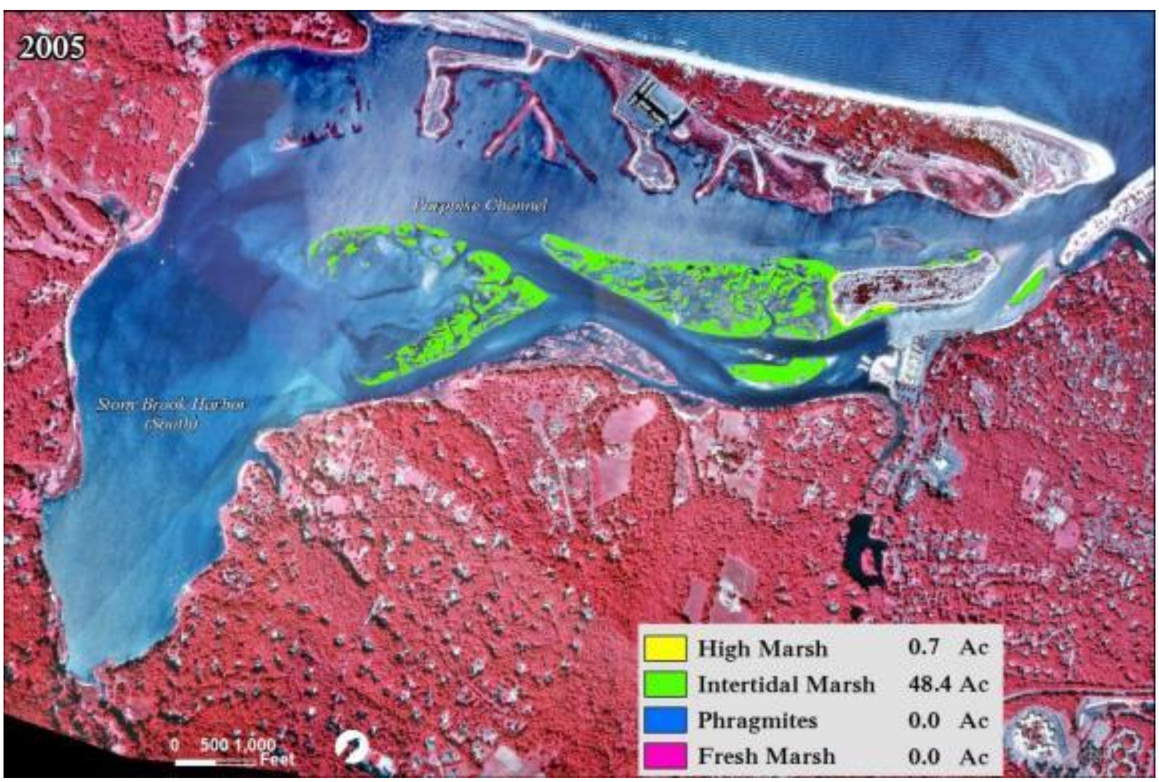
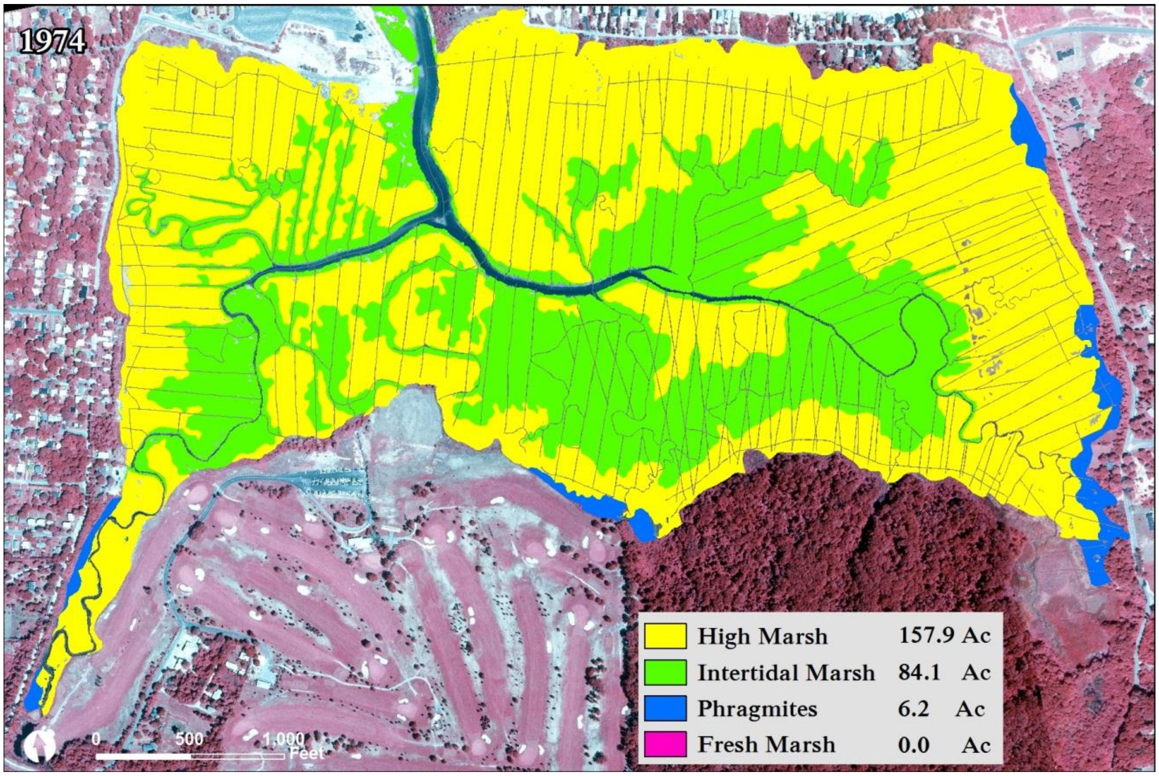


Figure 40: Crab Meadow (Complex ID #222)

[See Page D3, Appendix I for Locator Map]



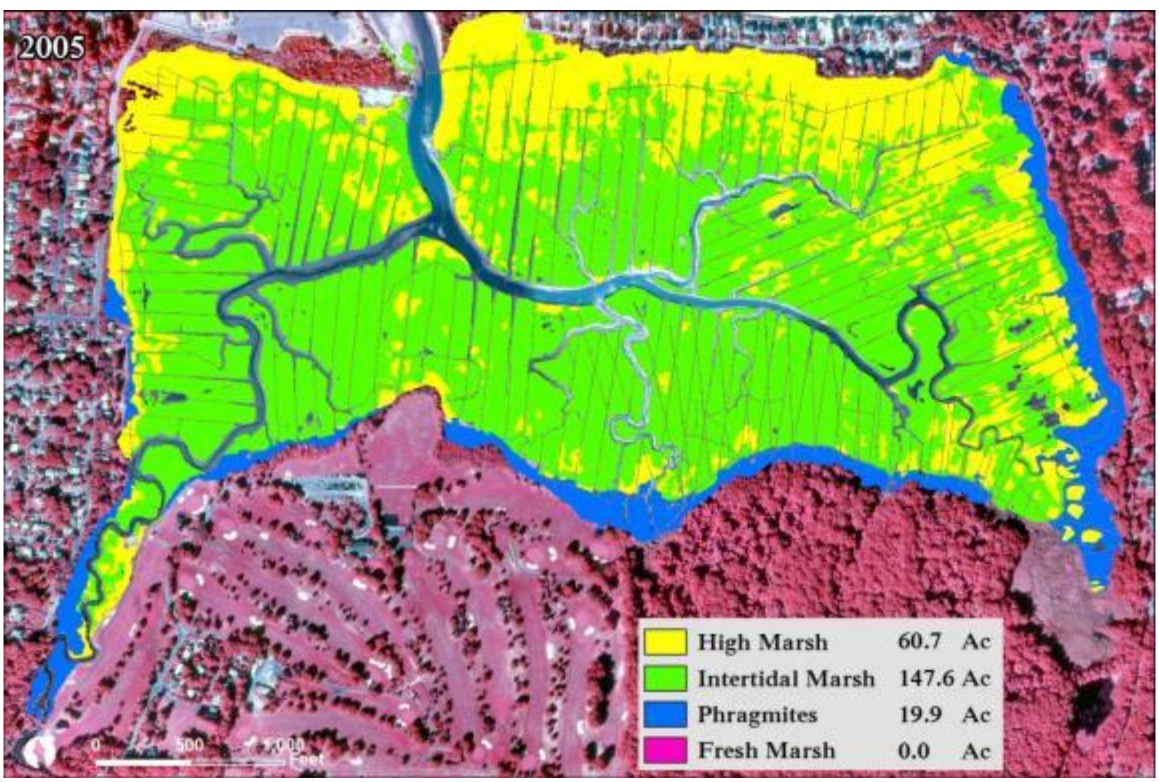
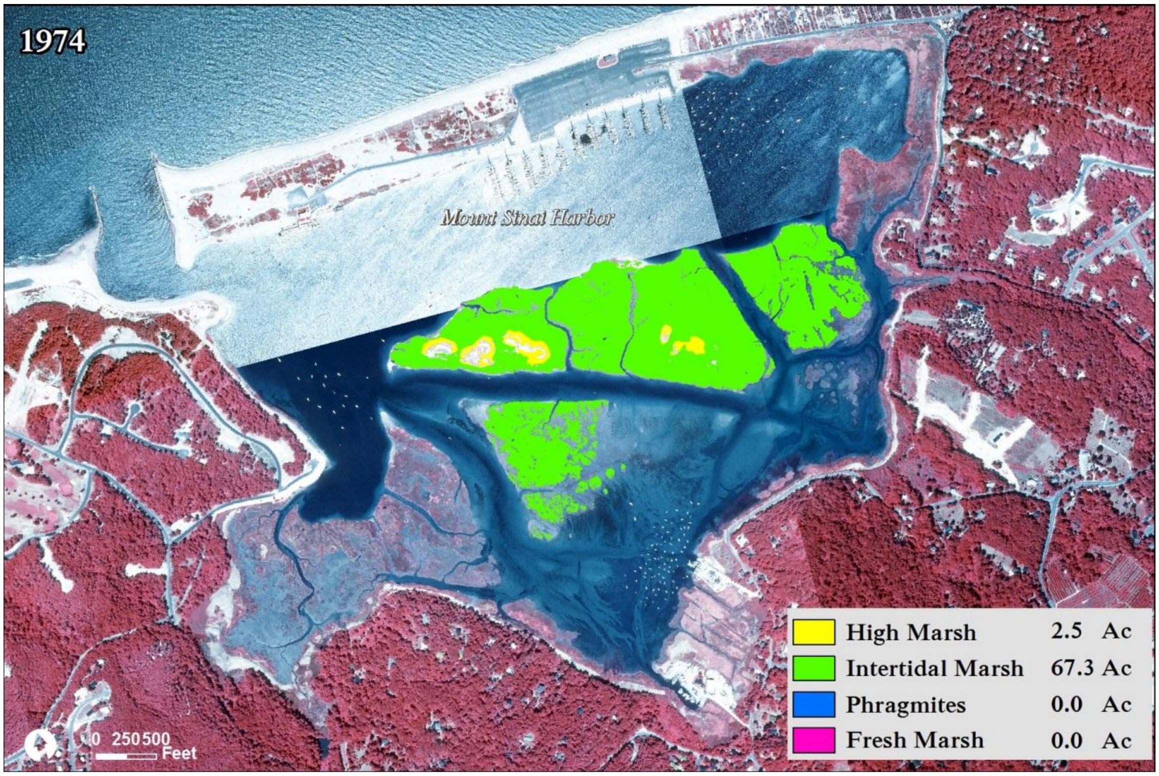


Figure 41: Mount Sinai Harbor Islands (Complex ID #90)
[See Page D5, Appendix I for Locator Map]



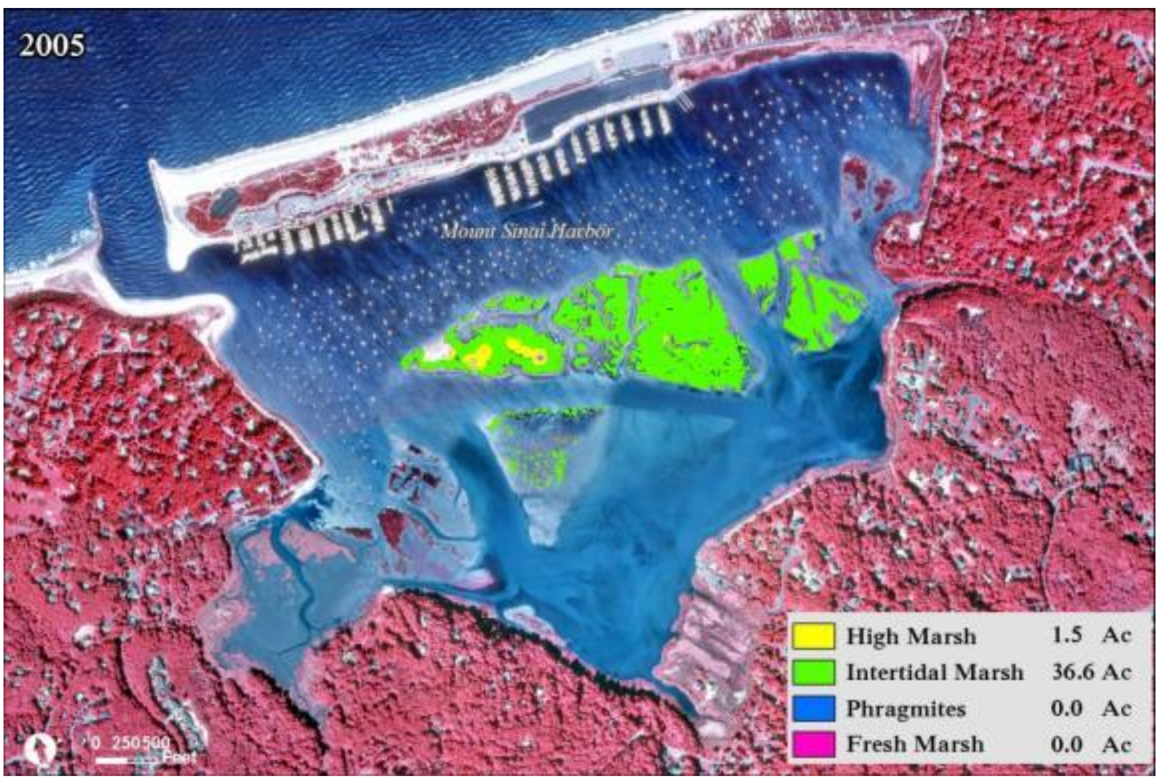
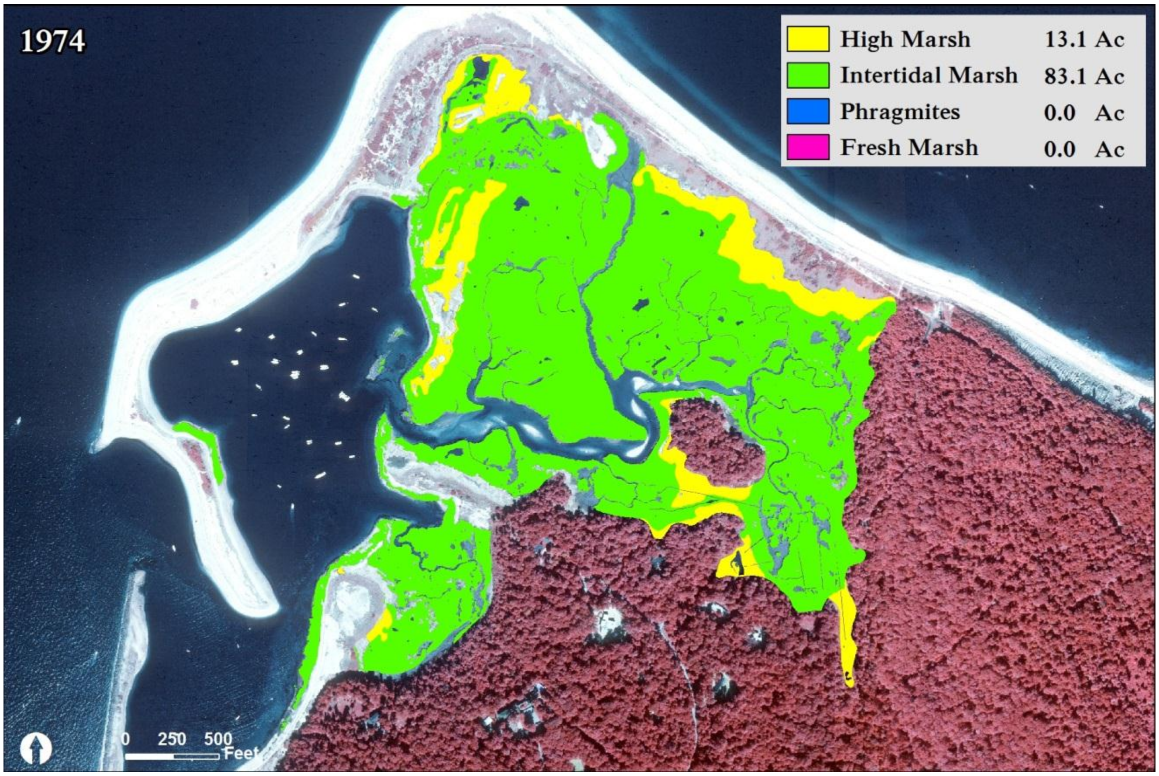


Figure 42: Lloyd Point Wetlands (Complex ID #236)

[See Page D2, Appendix I for Locator Map]



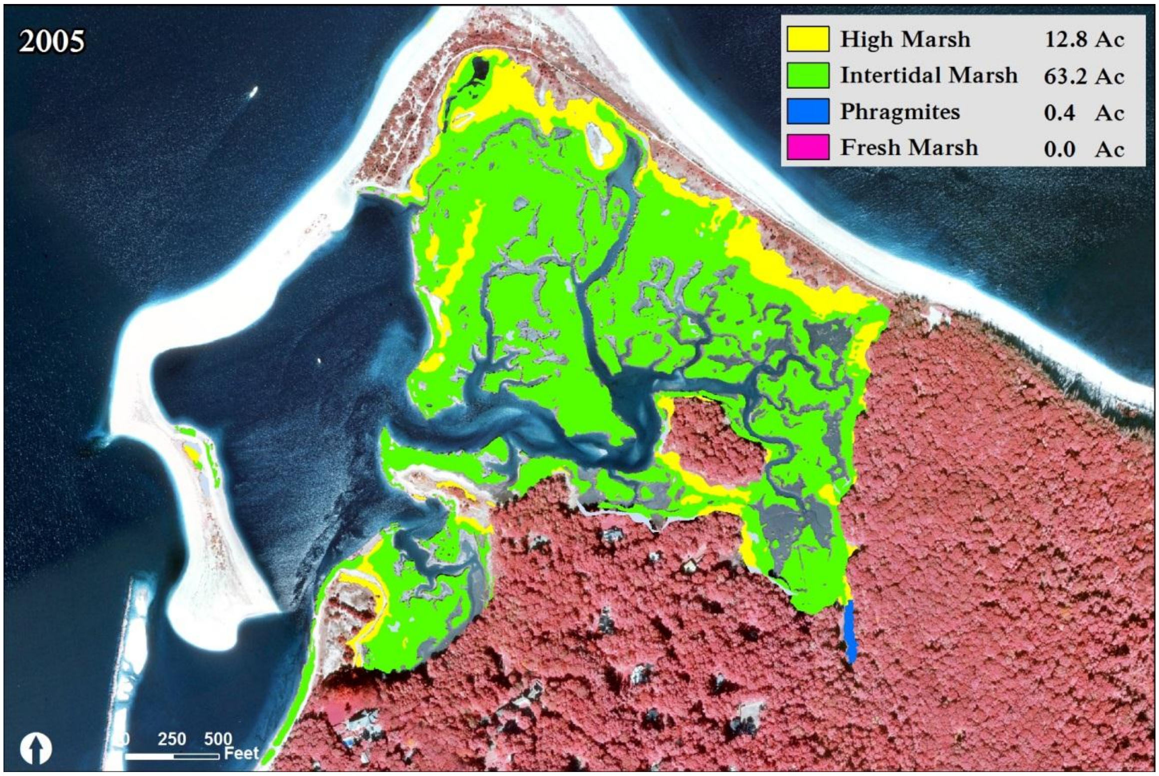
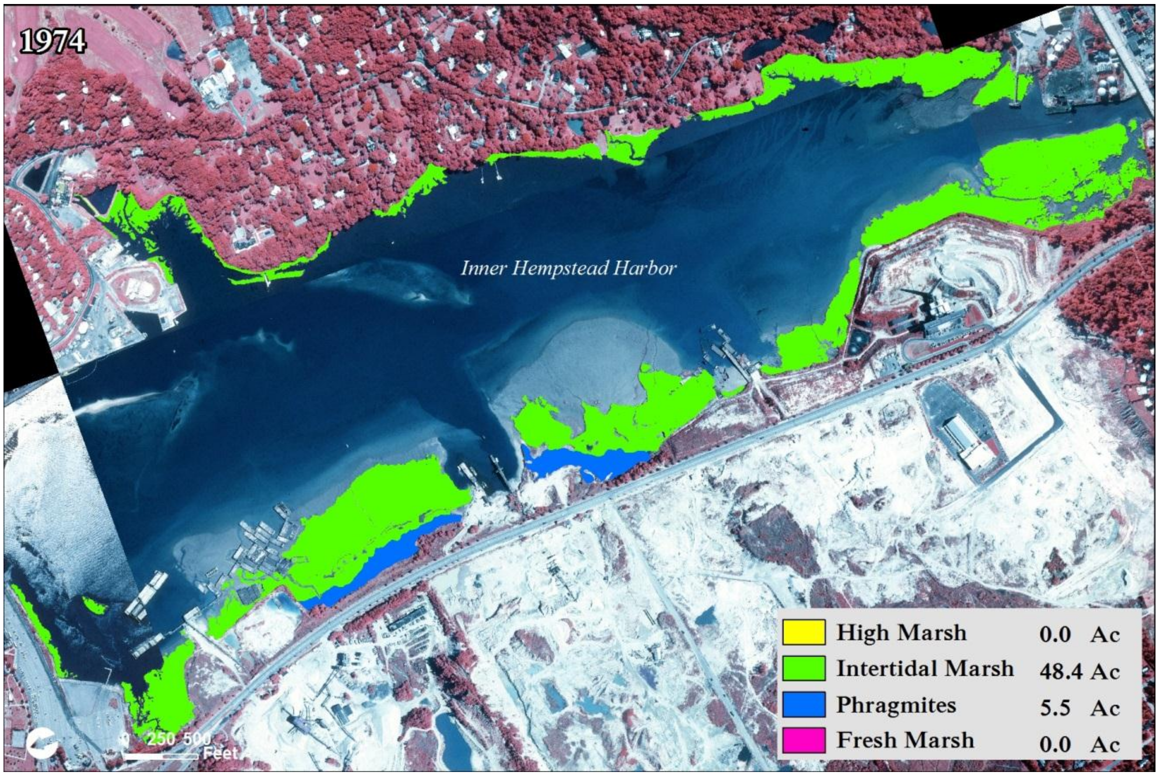


Figure 43: Inner Hempstead Harbor West (Complex ID #267)

[See Page E2, Appendix I for Locator Map]



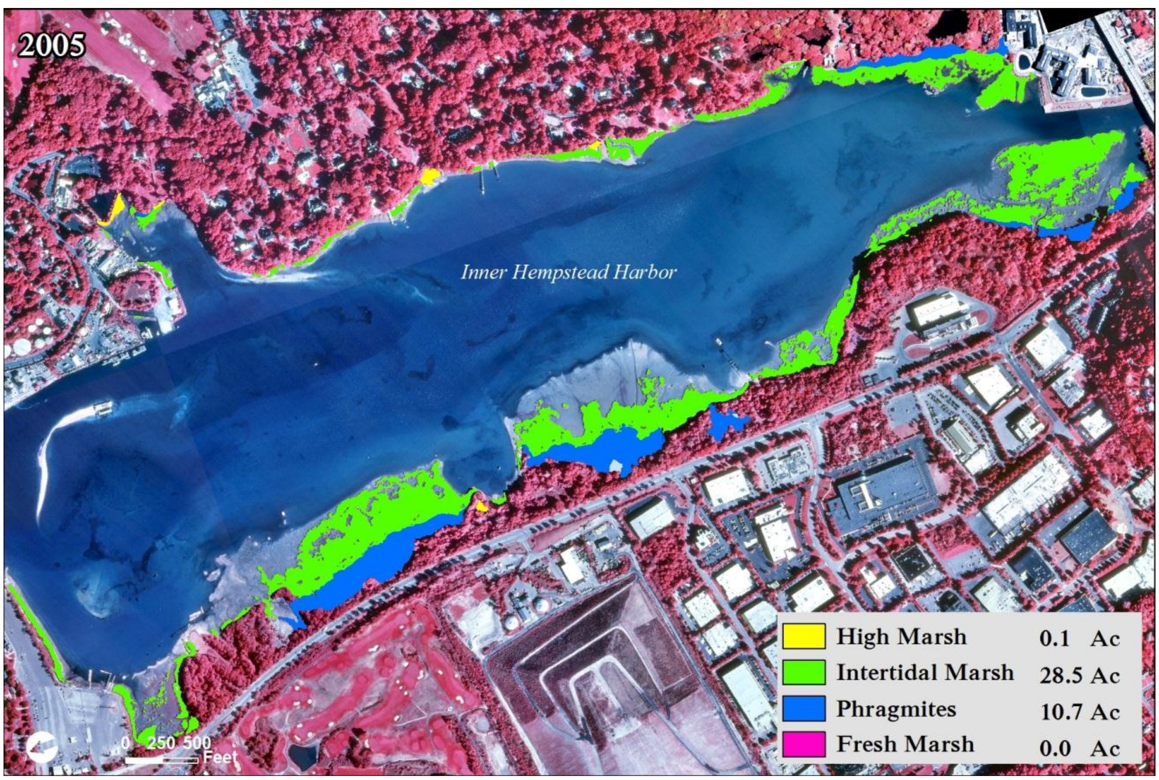
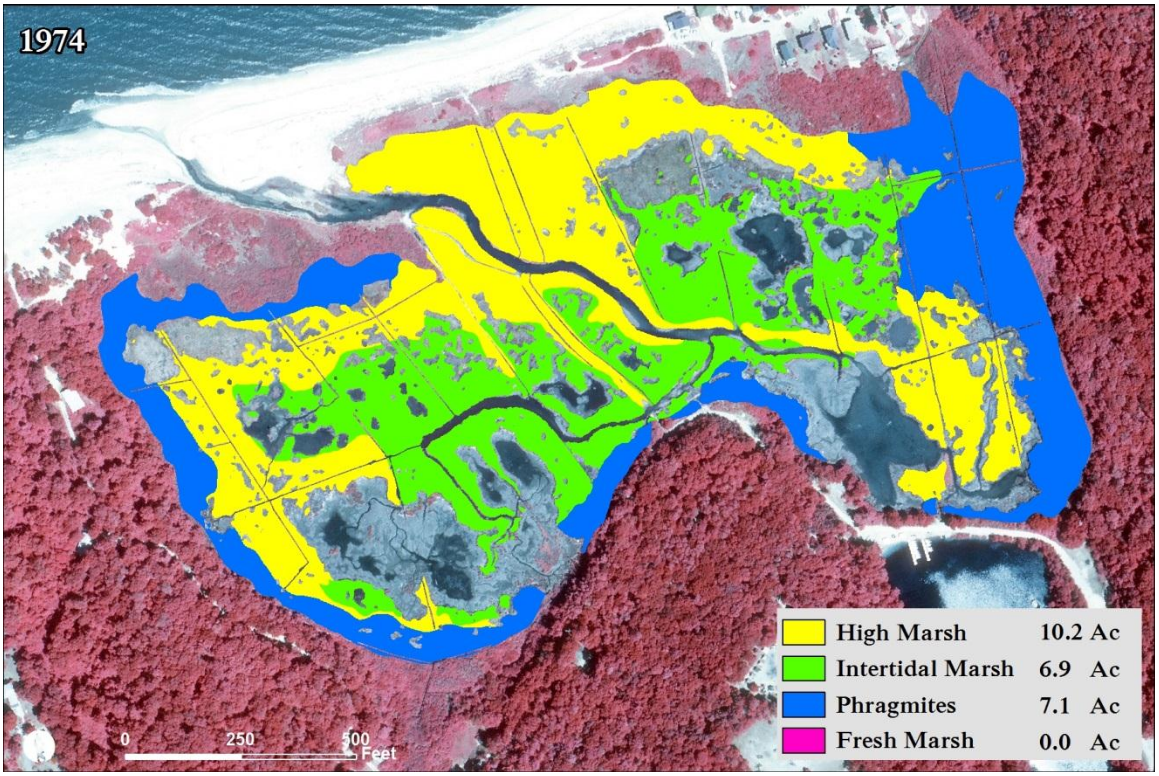


Figure 44: Baiting Hollow (Complex ID #85)
[See Page D6, Appendix I for Locator Map]



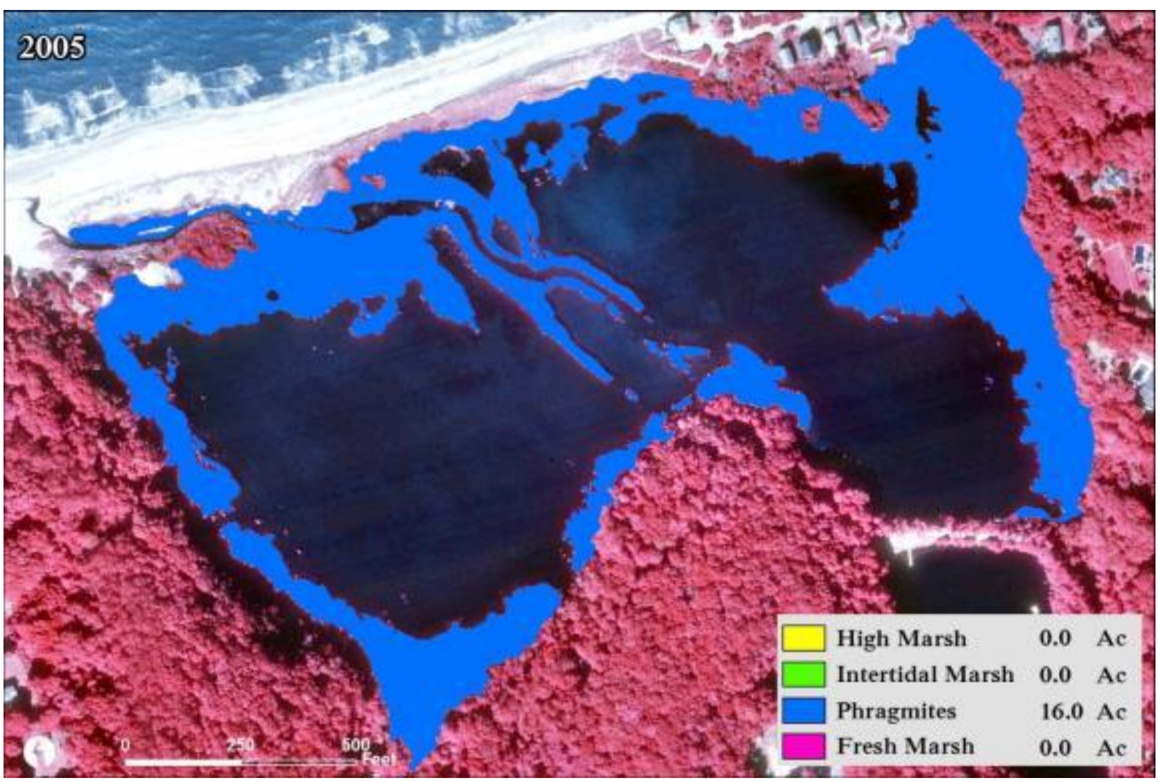


Figure 45: Sheets Creek Channel (Complex ID #275)

[See Page E1, Appendix I for Locator Map]

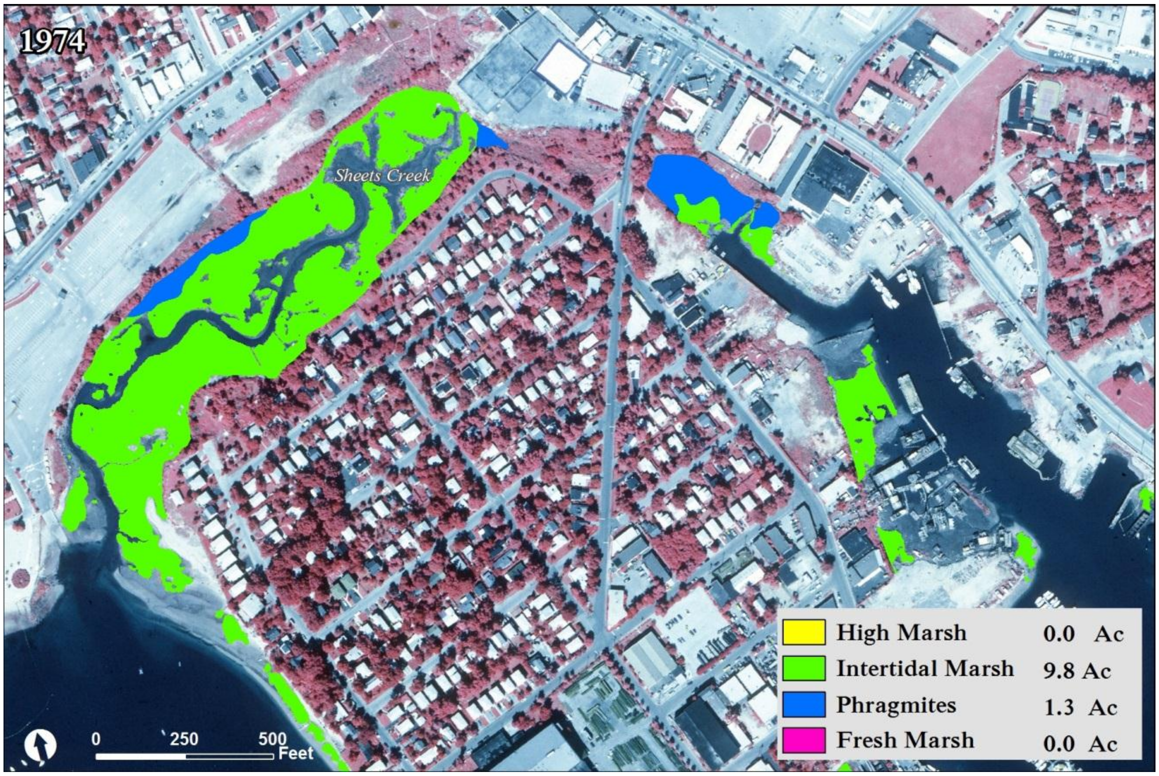
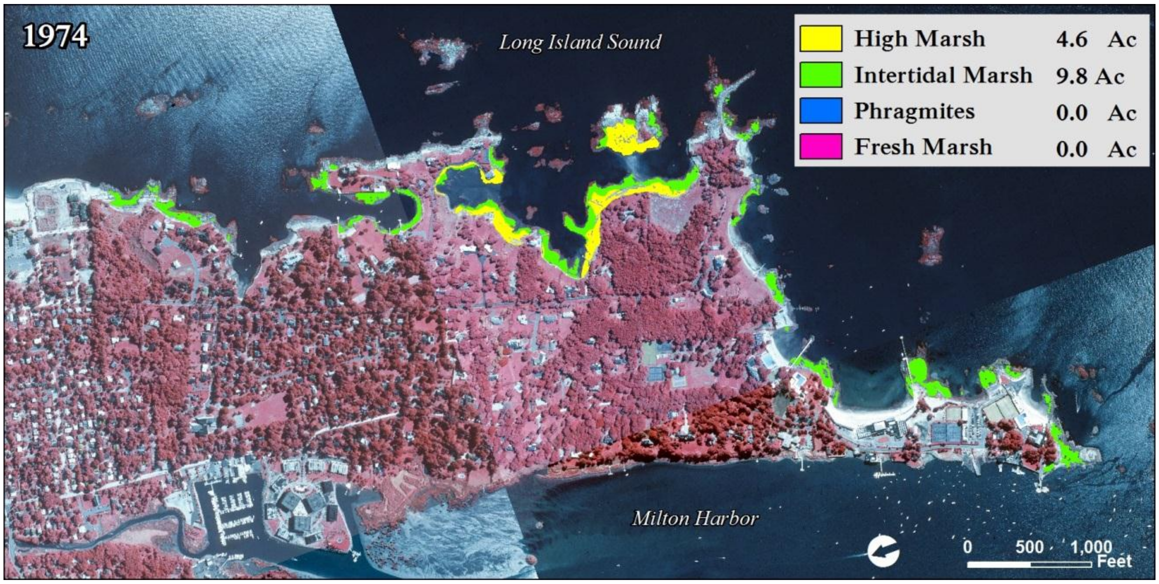


Figure 46: Long Island Sound-Milton Point to Rye Beach (Complex ID #314)
[See Page D1, Appendix I for Locator Map]



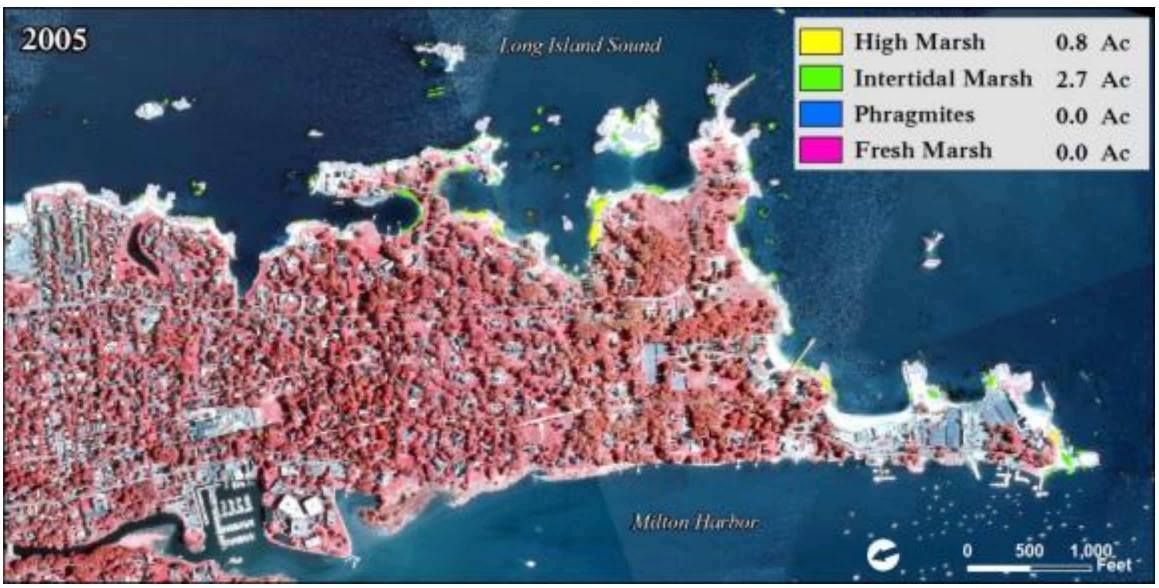
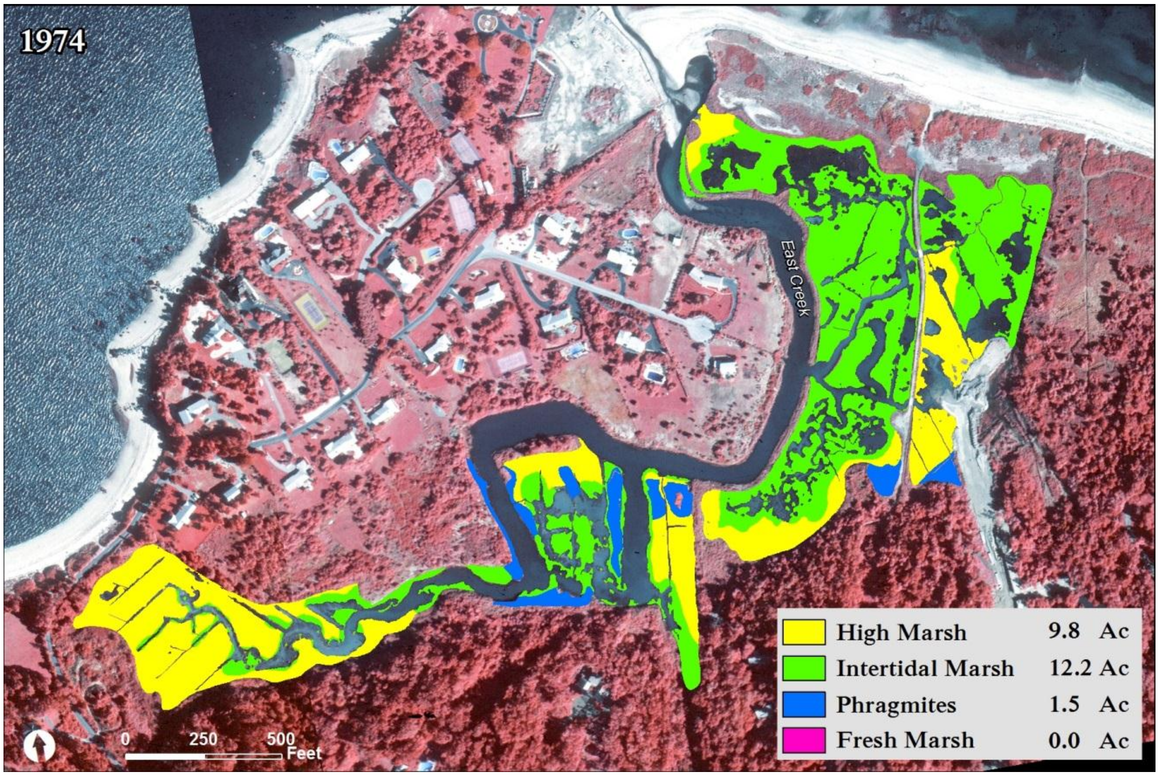


Figure 47: Prospect Point/East Creek (Complex ID #272)

[See Page D1, Appendix I for Locator Map]



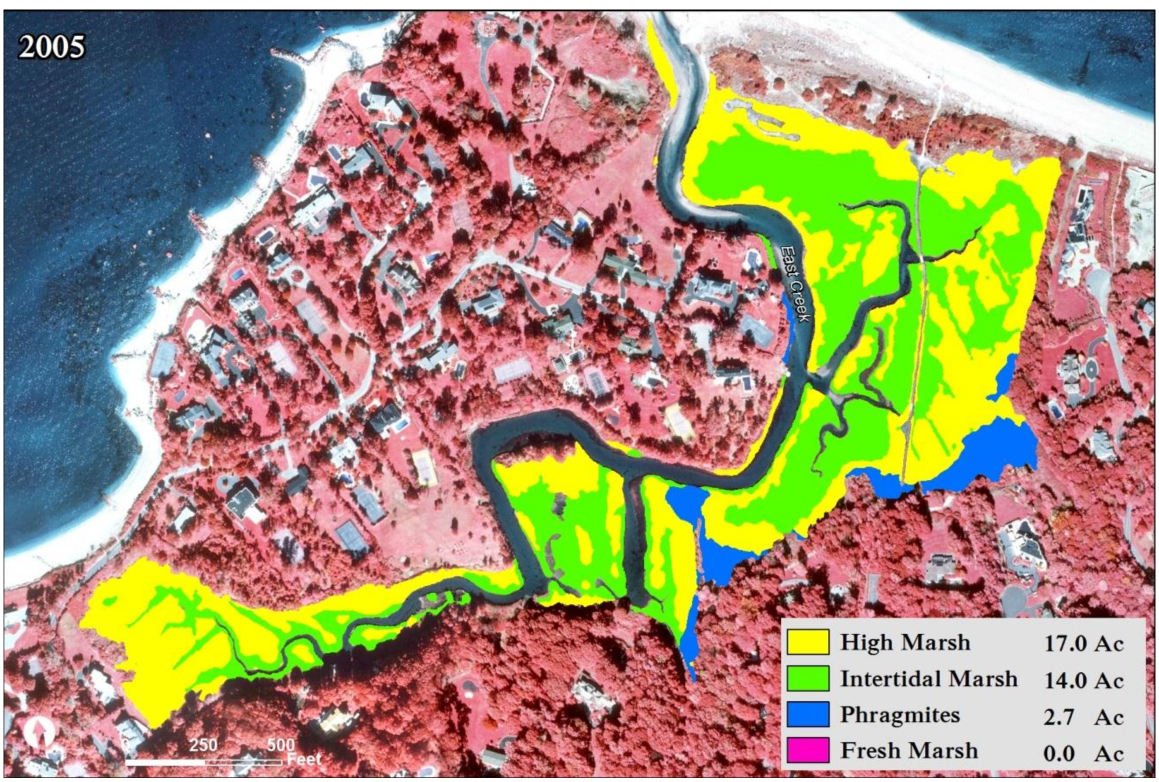
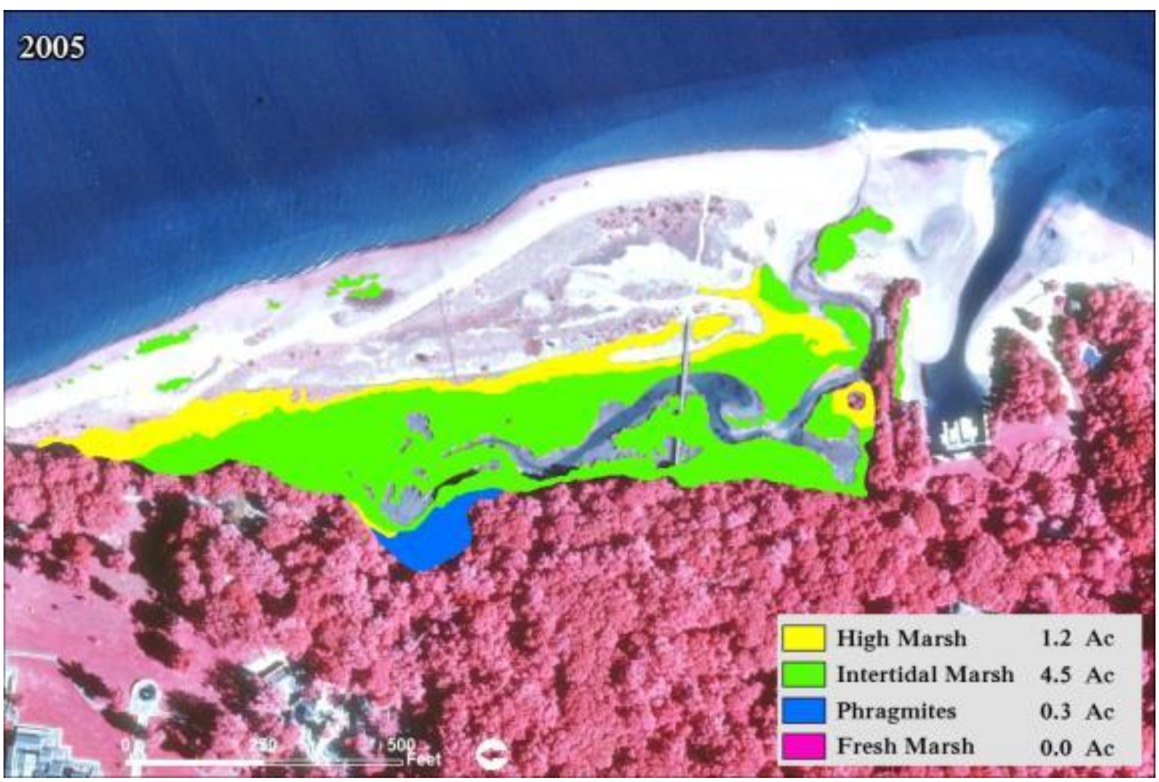


Figure 48: Sagamore Hill Marsh (Complex ID #243)
[See Page D2, Appendix I for Locator Map]



Peconic Estuary

The Peconic Estuary was divided into 159 marsh complexes, ranging in size from less than 1 acre to 253 acres of vegetated tidal wetlands. At the estuary level, the Peconic Estuary exhibited a lower percentage of native marsh loss (10.5 percent, or 362.8 acres) than the Long Island Sound, South Shore Estuary, and South Fork Ponds (Table 3).

Table 37: Tidal Wetland Area Change (1974-2005) in the Peconic Estuary by Class

Wetland Type	1974 Wetland Area (acres)	2005 Wetland Area (acres)	Change (%)
Intertidal Marsh	1,457.1	1,652.6	13.4
High Marsh	1,865.9	1,393.8	-25.3
Coastal Fresh Marsh	117.2	31.0	-73.5
Marsh Subtotal	3,440.2	3,077.4	-10.5
Phragmites australis	304.3	573.6	88.5
Vegetated Area Total	3,744.5	3,651.0	-2.5

The Peconic Estuary spans the Towns of East Hampton, Riverhead, Shelter Island, Southampton and Southold. As shown in Table 38, most of the Peconic Estuary's Year 2005 marsh habitat (91%) is evenly distributed among the Towns of East Hampton (908.3 acres), Southampton (1,048.7 acres), and Southold (850.6 acres). East Hampton sustained the largest loss of marsh habitat, losing 145.8 acres for a 13.8 percent decrease from 1974 to 2005. The Town of Southold lost nearly 10 percent of marsh habitat from 1974 through 2005, while the Town of Riverhead exhibited a slight gain in native tidal wetland area. The highest percentage loss of marsh habitat occurred in the Town of Shelter Island where marsh habitat decreased in area by 17.5 percent.

Table 38: Tidal Wetland Area Change in the Peconic Estuary by Town

Municipality	1974 IM+HM+FM (acres)	2005 IM+HM+FM (acres)	Δ IM+HM+FM (acres)	Δ IM+HM+FM (%)
East Hampton	1,054.1	908.3	-145.8	-13.8
Riverhead	51.9	57.1	5.2	+9.9
Shelter Island	258.0	212.8	-45.2	-17.5
Southampton	1,133.4	1,048.7	-84.7	-7.5
Southold	942.8	850.6	-92.2	-9.8
Total	3,440.2	3,077.4	-362.8	-10.5

Despite lower rates of tidal wetland loss compared to other Long Island estuaries, indicators of significant marsh change and deterioration were also observed in the Peconic Estuary's wetlands. For example, high marsh habitat in the Peconic Estuary decreased by approximately 25.3 percent from 1974 to 2005 (Table 37). Several Peconic Estuary wetland complexes, including Accabonac Harbor (ID # 156), Northwest Creek (ID # 165), Napeague Meadows (ID # 154), are among the marsh complexes with the greatest observed losses of high marsh (in acreage and percentage) (Table 39). In the Peconic Estuary, areas of lost high marsh generally converted to intertidal marsh or were overtaken by *Phragmites australis* with less panne or pond formation than the other Long Island estuaries. Reduced panne formation and reduced erosion of the seaward edge of marshes in the Peconic is the likely explanation for the high rate of high marsh loss and lower rate of overall native marsh area loss compared to the other estuaries (Table 3). For example, intertidal marsh in the Peconic Estuary increased by 13.4 percent between 1974 and 2005 compared to a -25 and -1 percent reduction in the Long Island Sound and South Shore Estuary, respectively. This conversion of high marsh to intertidal marsh is apparent in Figure 49-Figure 52 showing Accabonac Harbor, Northwest Creek, West Neck Creek (ID # 196), and Napeague Meadows. These complexes with the highest acreage and percentage of high marsh loss were also among the complexes with the greatest increase in intertidal marsh area.

Table 39: Complexes with Largest Tidal Wetland Area Loss in the Peconic Estuary

Complex (ID#)	1974 IM+HM+FM (acres)	2005 IM+HM+FM (acres)	Δ IM+HM+FM (acres)	Δ IM+HM+FM (%)
Accabonac Harbor (156)	260.9	214.4	-46.5	-17.8
Northwest Creek (165)	162.4	137.2	-25.2	-15.5
Gardiner's Island Bostwick Creek (109)	27.3	4.4	-22.9	-83.8
West Neck Creek (196)	218.5	201.6	-16.9	-7.7
Little Reed Pond (150)	20.5	5.4	-15.1	-73.8
Little Northwest Creek (167)	47.0	33.3	-13.7	-29.1
Goose Creek (11)	72.8	59.3	-13.4	-18.5
Little Sebonac Creek/Sebonac Island (197)	79.9	66.8	-13.1	-16.4
Richmond Creek (58)	36.3	24.7	-11.8	-32.4
Alewife Brook & Pond (163)	32.3	22.2	-10.1	-31.2

Another primary mechanism of native marsh loss in the Peconic Estuary is the expansion of invasive *Phragmites australis*. *Phragmites australis* abundance in the Peconic Estuary increased by 88.5 % (270 acres) from 1974 to 2005. The Peconic Estuary had a greater increase in percentage of *Phragmites australis* than the Long Island Sound (106.6 acres, +33.6%) and the

Fire Island Inlet to Smith Point reach of the South Shore Estuary (157.9 acres, +20.1%); the South Fork Ponds (Mecox Bay, Sagaponack Pond, and Georgica Pond) incurred the greatest increase in *Phragmites australis* expansion (85.0 acres, +395.7%) (Table 11). Large expansion of *Phragmites australis* stands is apparent at Accabonac Harbor, Northwest Creek, Gardiner's Island Bostwick Creek (ID # 109), Little Reed Pond (ID # 150), Plum Pond (ID # 126), and a portion of the Peconic River (ID # 2) (Figure 49, Figure 50, and Figure 53-Figure 56). These complexes were also among the complexes with the largest decreases in native marsh habitats in the Peconic Estuary (Table 39 and Table 40).

Table 40: Complexes with Highest Percent Loss of Tidal Wetlands in the Peconic Estuary

Complex (ID #)	1974 IM+HM+FM (acres)	2005 IM+HM+FM (acres)	Δ IM+HM+FM (%)	Δ IM+HM+FM (acres)
Gardiner's Island Bostwick Creek (109)	27.29	4.43	-83.8	-22.9
Little Reed Pond (159)	20.48	5.37	-73.8	-15.1
Plum Pond (126)	13.07	3.67	-71.9	-9.4
Peconic River Tributary (2)	12.31	4.66	-62.1	-7.7
Gardiner's Island Tobaccolot Pond (116)	19.04	9.44	-50.4	-9.6
Gardiner's Island Little Pond (113)	10.10	5.64	-44.2	-4.7
Brushs Creek (70)	10.35	6.67	-35.6	-3.7
Dam Pond (34)	15.59	10.11	-35.1	-5.5
Deep Hole Creek (67)	13.30	8.90	-33.1	-4.4
Richmond Creek (58)	36.51	24.68	-32.4	-11.8

Table 39 lists the marsh complexes that have sustained the largest reductions in native marsh habitat from 1974 through 2005. The top five marshes, in terms of area of habitat loss, are depicted in Figure 49-Figure 51, Figure 53, and Figure 54. Collectively, the ten marshes listed in Table 39 account for approximately 52 percent of all marsh habitat loss in the Peconic Estuary. With six of the 10 most heavily affected marshes are located in the Town of East Hampton.

Table 40 lists the percent loss of habitat for the ten marshes that sustained the highest proportion of marsh loss from 1974 to 2005. Though the figures for percent of marsh loss are high, e.g., ranging from 32.4 to 83.8 percent, the actual losses in marsh habitat area are relatively small, especially in comparison with the ten largest marsh habitat losses provided in Table 40. The percentage losses listed in Table 39 were sustained by marshes that are relatively small in area. In fact, with two exceptions, the marshes listed in Table 40 are smaller than the average marsh size for the Peconic Estuary. If the list of marshes in Table 40 were to be expanded to include the next 20 marshes, then the top 30 marshes by highest percent of marsh loss would comprise only 31 percent of total marsh loss in the estuary for Year 1974 to 2005. In contrast, by expanding to include the top 30 marshes in terms of area loss, these 30 marshes would account for 86.1 percent of the total marsh loss in the Peconic Estuary from 1974 to 2005. Thus, the distribution of marsh loss in the Peconic Estuary is skewed toward the larger marsh complexes.

Table 41: Complexes with Largest *Phragmites australis* Expansion in the Peconic Estuary

Complex (ID #)	1974 *Phragmites* (acres)	2005 *Phragmites* (acres)	Δ *Phragmites* (acres)
Accabonac Harbor (156)	2.9	41.4	38.4
Northwest Creek (165)	32.1	55.6	23.4
Gardiner's Island Bostwick Creek (109)	0.0	22.9	22.9
Alewife Brook & Pond (163)	1.1	16.5	15.4
Little Northwest Creek (167)	0.0	15.0	15.0
Little Reed Pond (150)	0.0	14.3	14.3
Gardiner's Island Tobaccolot Pond (116)	0.0	11.8	11.8
Oyster Pond (149)	1.8	11.3	9.5
Plum Pond (126)	0.4	9.7	9.3
Peconic Bay Boulevard (544)	11.1	19.4	8.3

The top ten marshes with respect to *Phragmites australis* expansion are listed in Table 41. Collectively, the expansion of *Phragmites australis* in these ten marshes represented 62.5 percent of the total *Phragmites australis* expansion in the Peconic Estuary. Increases in *Phragmites australis* in the Peconic Estuary occurred largely at the expense of coastal fresh marsh and high marsh communities. *Phragmites australis* encroachment resulted in a 73.5% decrease in the areas mapped as coastal fresh marshes in 1974 (Table 37). The proliferation of *Phragmites australis* in the Peconic Estuary is somewhat counter-intuitive considering the lower development density and, presumably, reduced nutrient impairment to ground and surface waters in eastern Long Island. However, while many areas of the Peconic Estuary have lower development density, the results of this study indicate that the impacts and disturbance to the Peconic's wetlands have been sufficient in magnitude for widespread invasion and expansion of this invasive species. *Phragmites australis* colonization and expansion within and adjacent to tidal wetlands has typically been attributed to disturbance of native wetland and upland communities, soil salinity, and nitrogen availability (Bertness and Silliman, 2003). This study did not review and compare *Phragmites australis* increases relative to existing surface or groundwater monitoring data. However, the proliferation of *Phragmites australis* in the Peconic Estuary, particularly its coastal fresh marsh habitats, emphasizes the importance of soil salinity, years since the initial invasion, the original species composition of the invaded wetland, and hydrological and physical characteristics of the invaded site's soils in explaining *Phragmites australis* invasions.

From 1974 through 2005, native marsh habitat expanded in 41 of the 159 marsh complexes in the Peconic Estuary, accounting for approximately 79.9 acres of new habitat (Table 42). This gain, however, was insufficient to offset marsh habitat losses. In 30 other complexes where marsh habitat increased – not including those listed in Table 42 – the expansion was less than 2 acres for each. Thus, gains in marsh habitat are skewed towards larger marshes. For example, the five marsh complexes listed in Table 42 accounted for more than half, or 53 percent, of the gains in tidal wetland area in the Peconic Estuary. Figure 52, Figure 57, and Figure 58 depict the marsh gains in Napeague Meadows (ID # 154), Napeague Harbor (ID # 153) and Cold Spring Pond West (ID # 204), respectively.

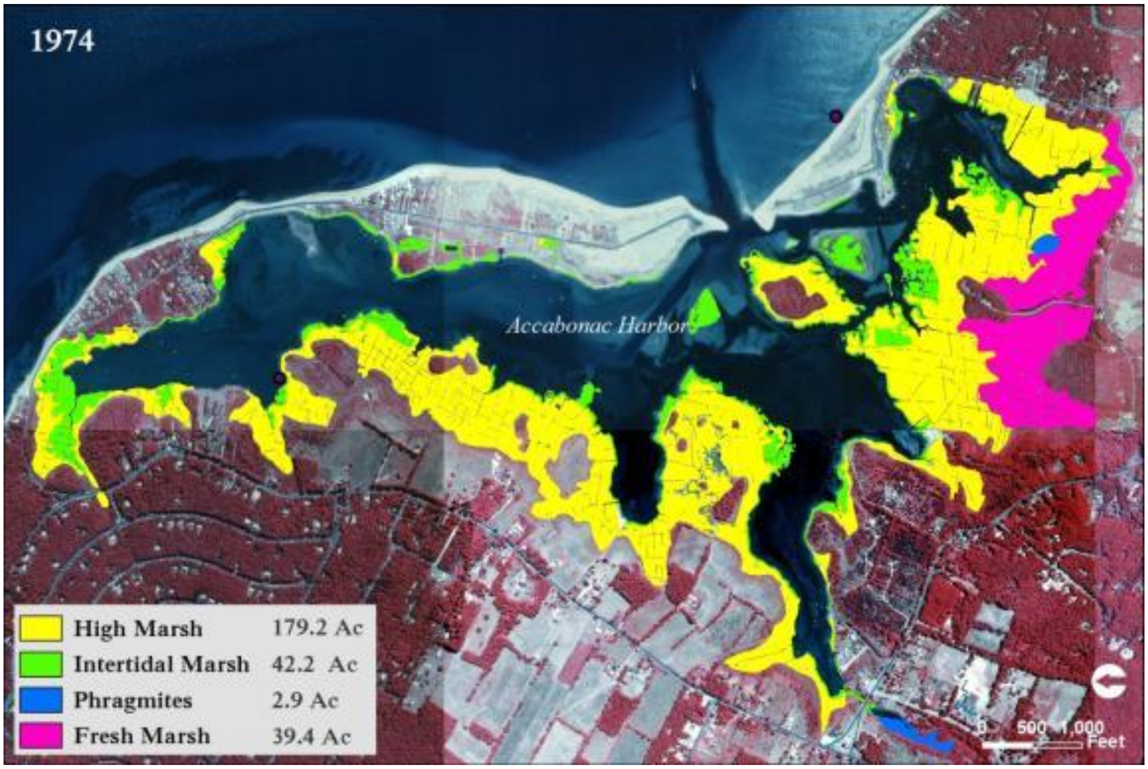
Table 42: Complexes with Largest Gain in Tidal Wetland Area in the Peconic Estuary

Complex (ID #)	1974 IM+HM+FM (acres)	2005 IM+HM+FM (acres)	Δ IM+HM+FM (acres)
Napeague Meadows (154)	237.0	253.0	16.0
Napeague Harbor (153)	29.5	39.8	10.3
Three Mile Harbor Shoreline (159)	7.7	12.1	4.4
Cold Spring Pond West (204)	2.2	6.9	4.7
Terry's Creek (81)	16.1	19.6	3.5
Hubbard Creek (14)	143.7	147.1	3.4

Gains in tidal wetlands areas can result from natural processes such as the conversion of *Phragmites australis* or low-lying upland habitats to tidal wetlands due to increased tidal inundation caused by either improved tidal exchange between the wetland and the bays or sea level rise. However, wetland complexes with large increases in tidal wetlands areas must be examined to verify that these increases are not due to improved identification of tidal wetlands during the current mapping effort. Figure 52 and Figure 57 for Napeague Meadows and

Napeague Harbor, respectively, show both actual and artifact increases in tidal wetlands. In the southwestern headwaters of the Napeague Meadows complex, coastal fresh marshes consisting of mixed stands of *Typha angustifolia*, *Phragmites australis*, *Baccharis halimifolia*, and other woody vegetation were located in the current study, but not the 1974 tidal wetlands inventory. However, actual increases in tidal wetlands are also observed in the northwestern portion of this complex, as high marsh vegetation appears to have expanded in low-lying sandy areas. Tidal wetland expansion also appears to have occurred on the eastern shore of Napeague Harbor (Figure 57) as *Iva frutescens* and herbaceous high marsh vegetation have increasingly colonized the low, sandy swales and brackish meadows of Goff Point likely due to increased, but infrequent, flooding from two small channels along the eastern shore of Napeague Harbor. Similar to Sagamore Hill (Figure 48), the landward migration of tidal wetlands on Long Island appears to occur in low-lying sandy areas adjacent to tidal wetlands where expansion is not impeded by development, topography, upland forests or hardwood swamps, or *Phragmites australis*–dominated marshes or uplands. Cold Spring Pond West (ID # 204) in Sebonac (Southampton) shows a natural expansion of tidal wetland vegetation (approximately 3.7 acres) along the northern and southern shorelines of Cold Spring Pond (Figure 58). It is likely that some of this expansion has resulted from recovery of the tidal wetlands communities after the dredging and disturbance associated with the development of the residential neighborhood on Sandgate and Lands End Lanes. However, Cold Spring Harbor is consistent with Napeague Harbor and Sagamore Hill in that tidal wetlands expansion and landward migration appear to occur most frequently on sparsely vegetated sandy areas with shallow slopes.

Figure 49: Accabonac Harbor (Complex ID #156)
[See Page C10, Appendix I for Locator Map]



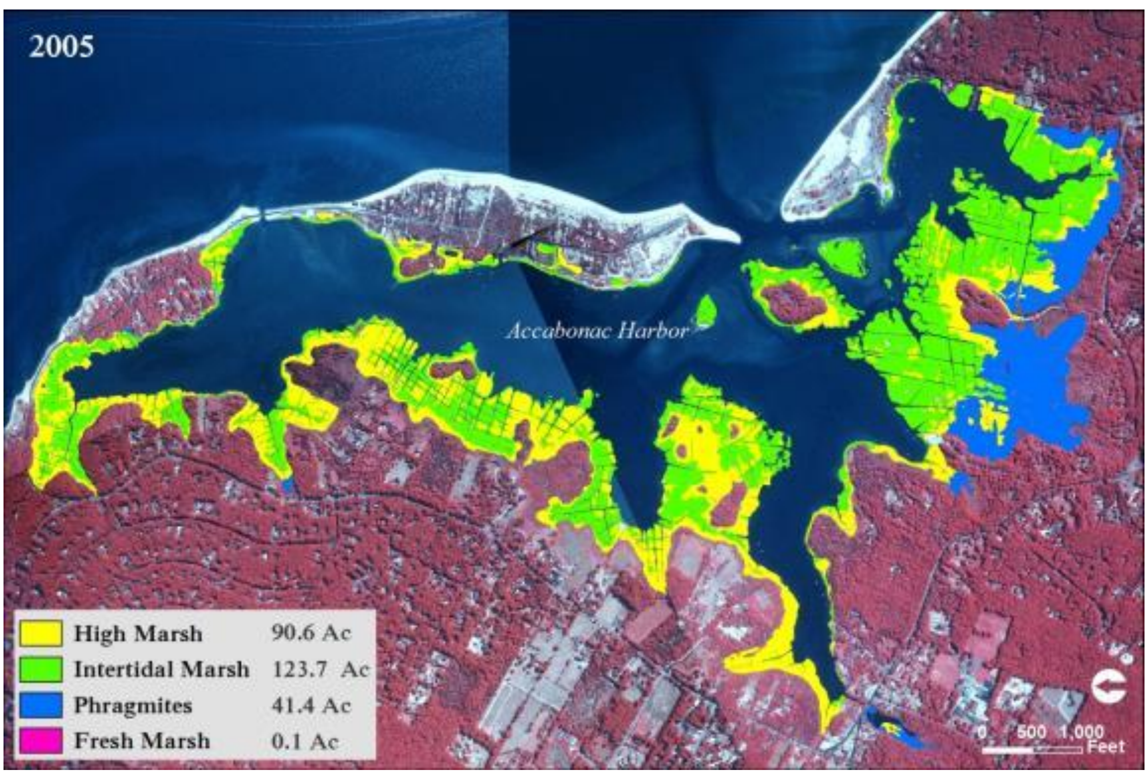
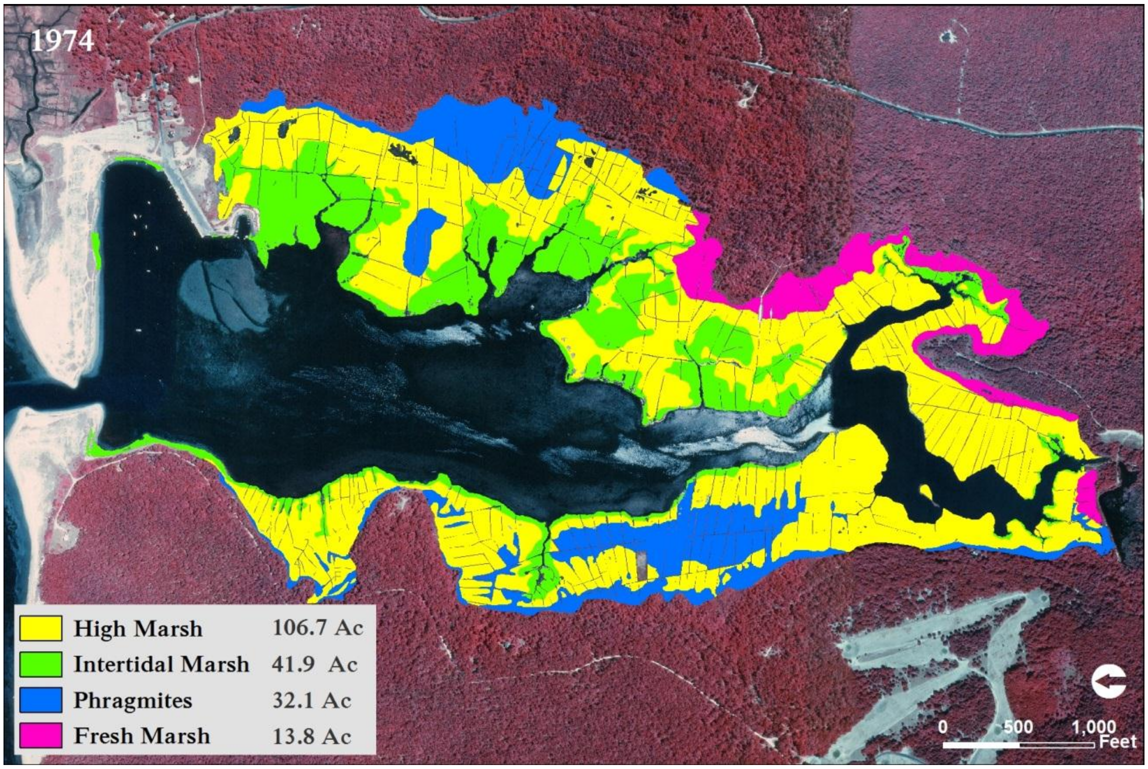


Figure 50: Northwest Creek (Complex ID #165)
[See Page C9, Appendix I for Locator Map]



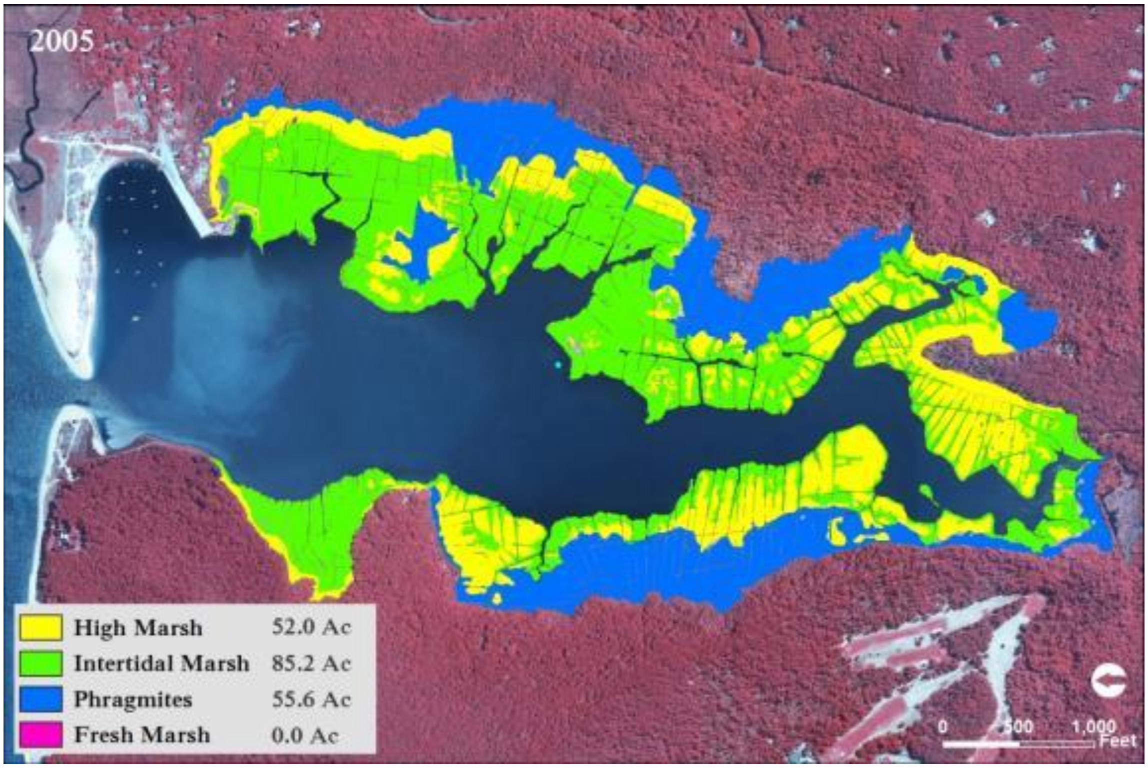
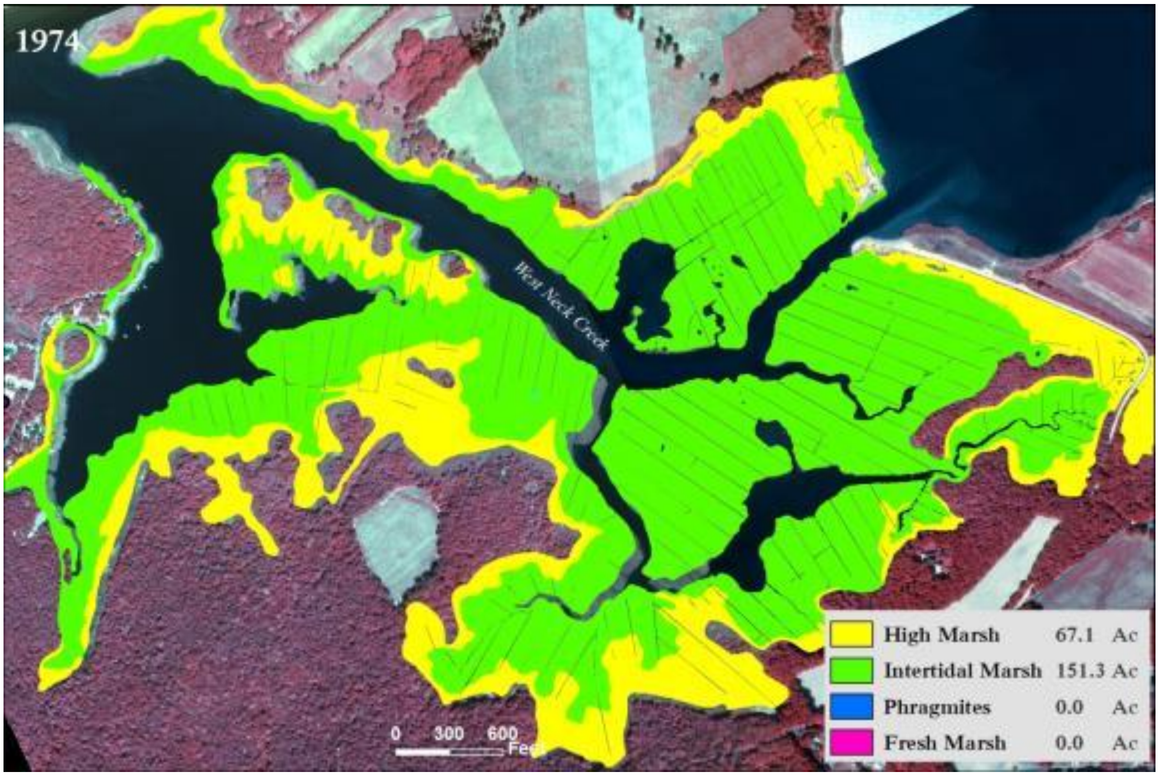


Figure 51: West Neck Creek (Complex ID #196)
[See Page D8, Appendix I for Locator Map]



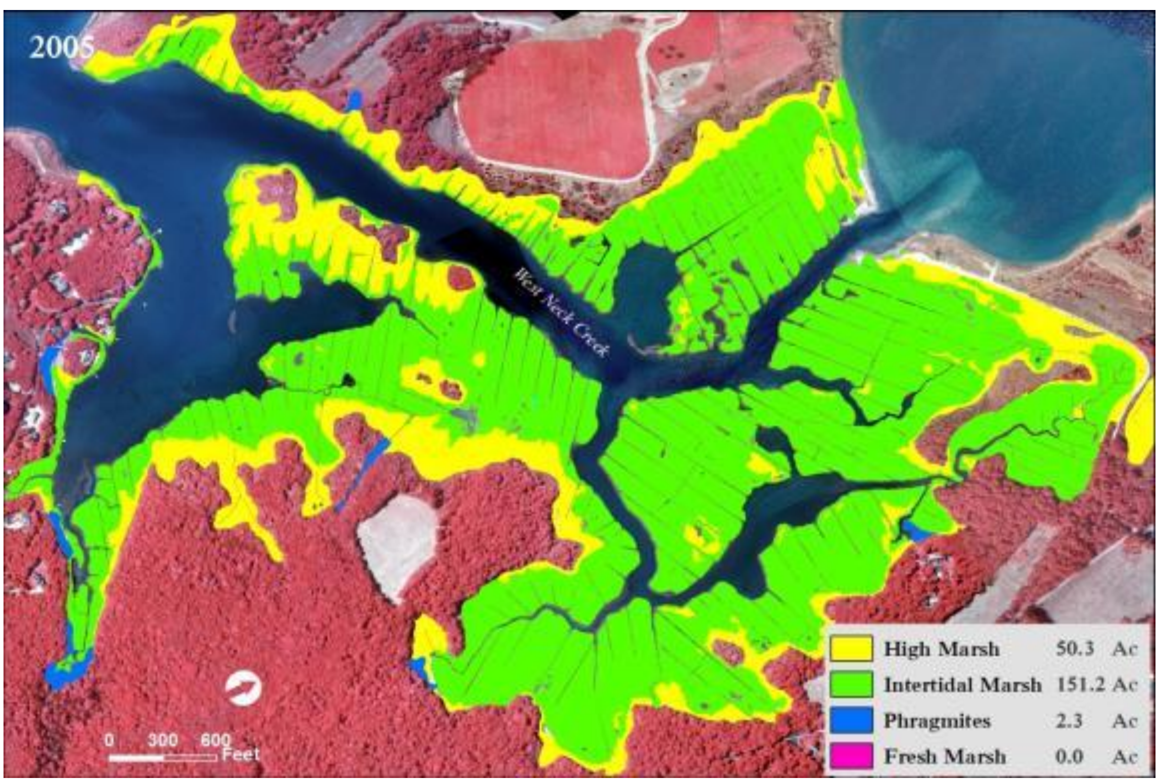
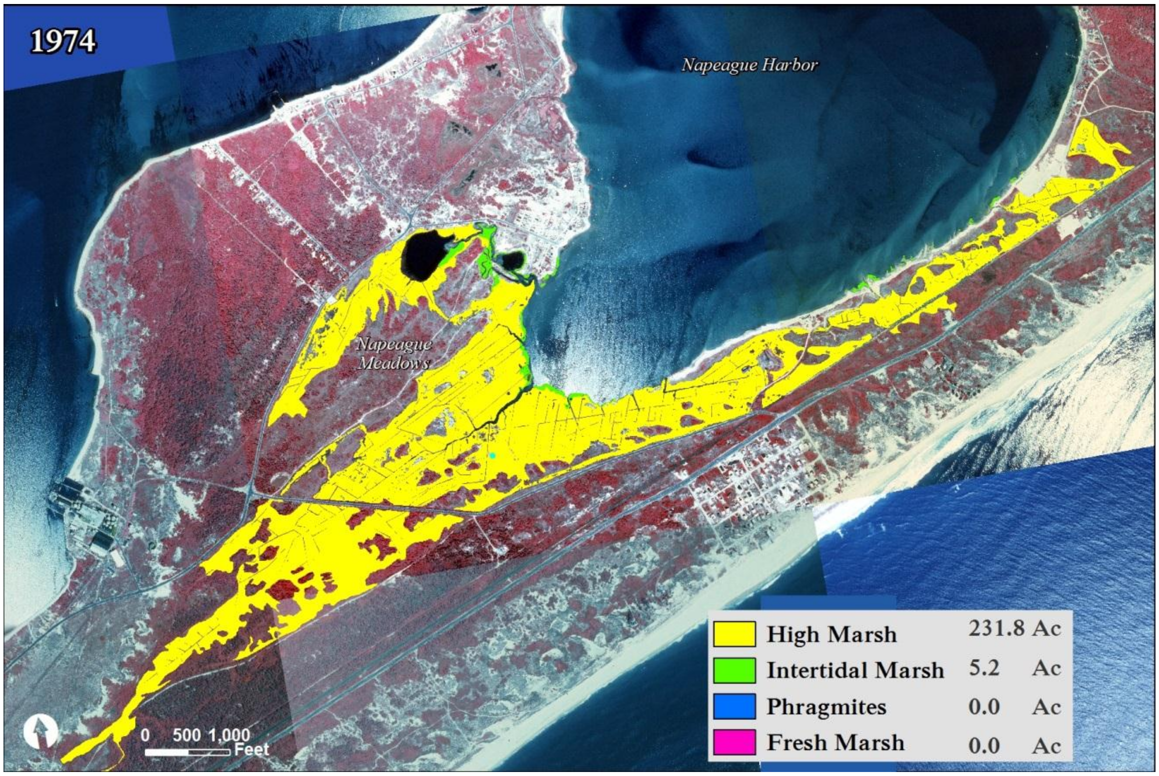


Figure 52: Napeague Meadows (Complex ID #154)
[See Page C10, Appendix I for Locator Map]



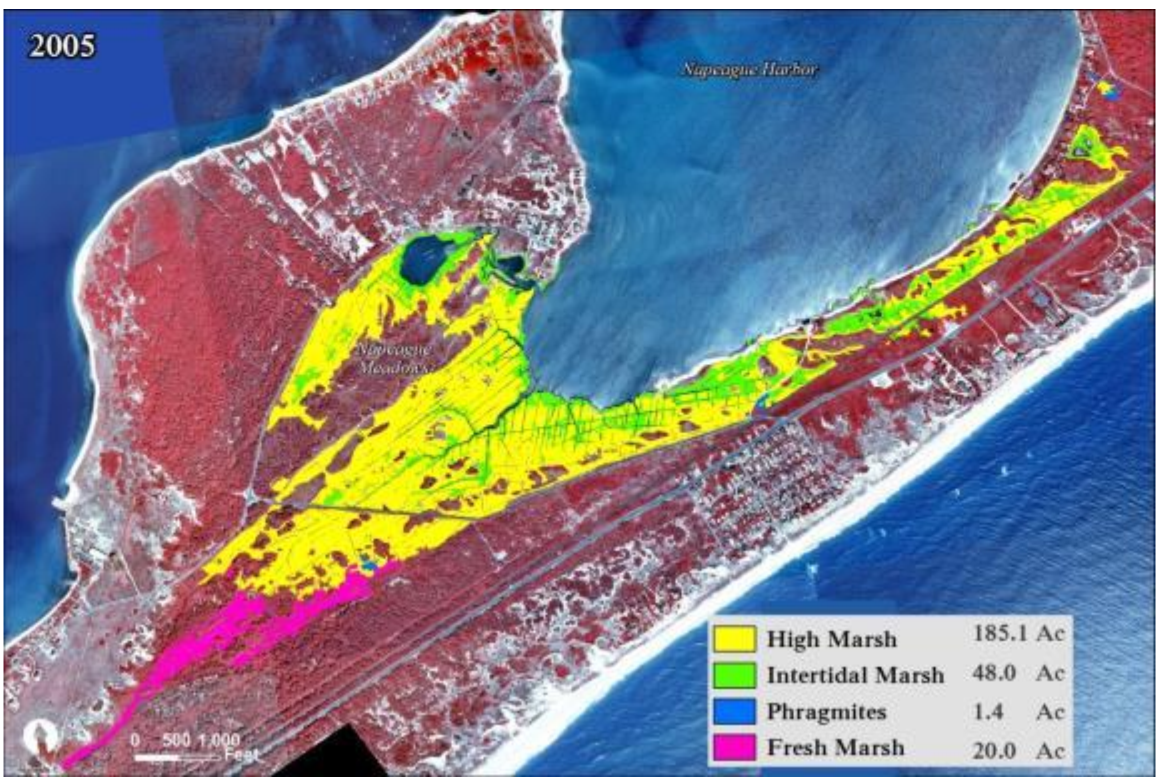
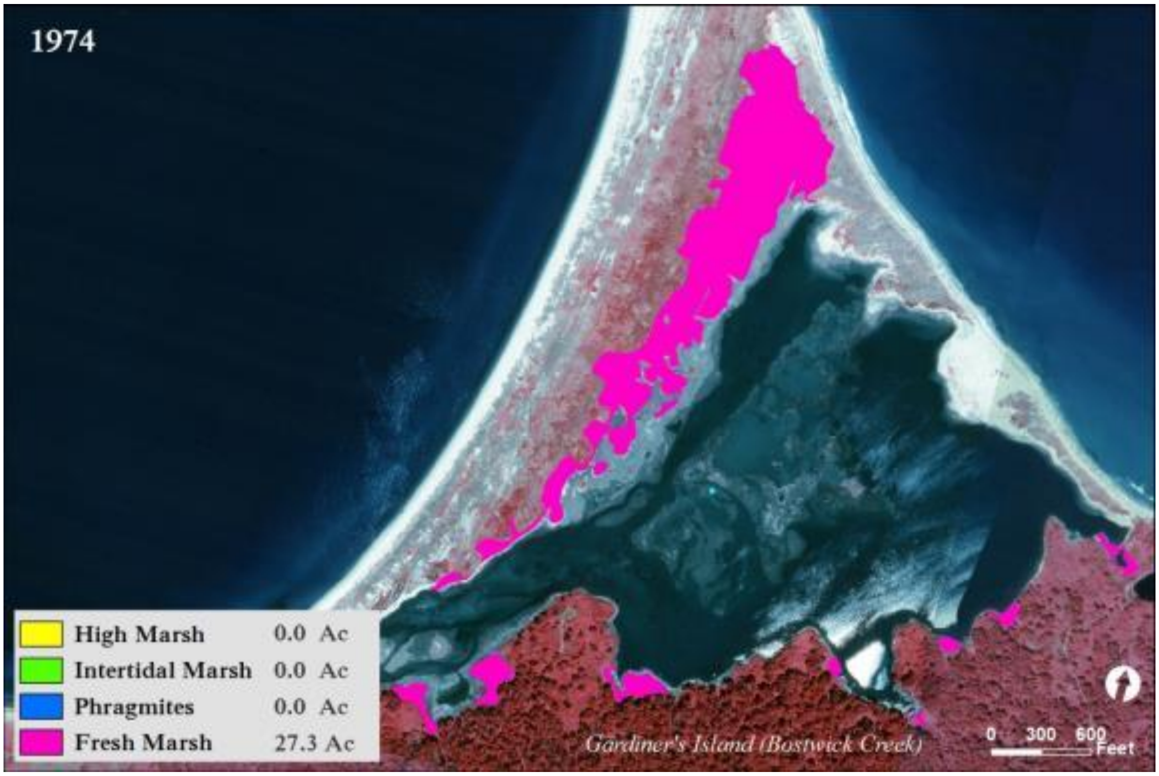


Figure 53: Gardiner's Island Bostwick Creek (Complex ID #109)

[See Page C10, Appendix I for Locator Map]



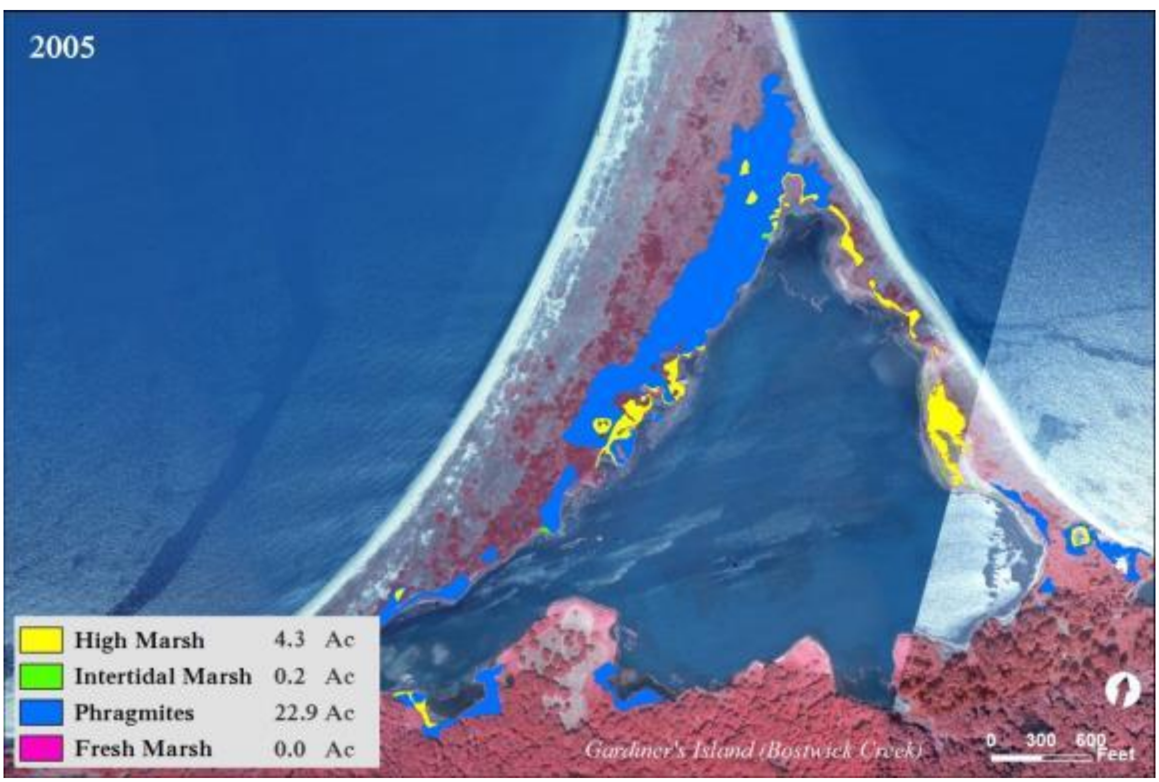


Figure 54: Little Reed Pond (Complex ID #150)
[See Page C11, Appendix I for Locator Map]

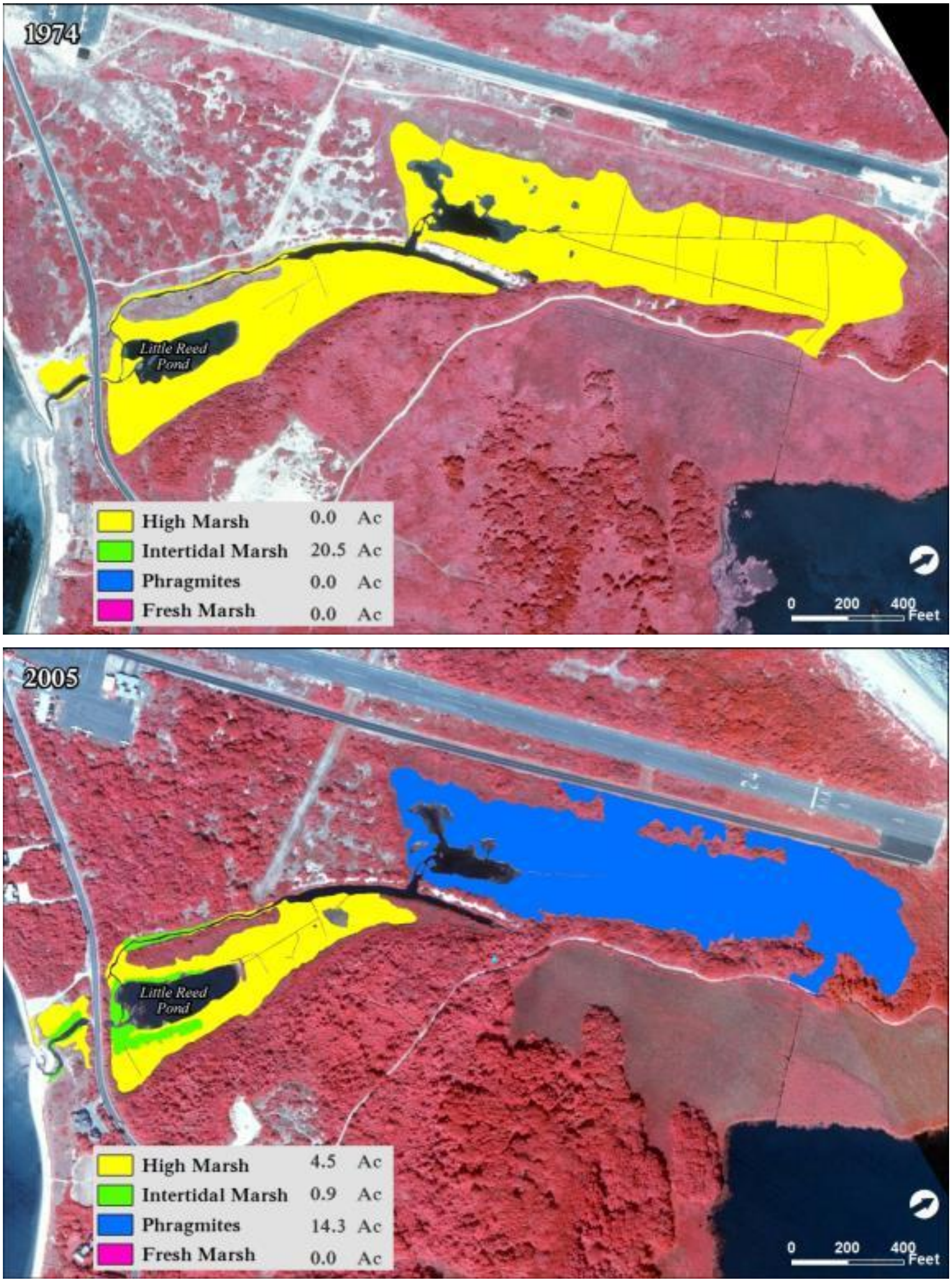
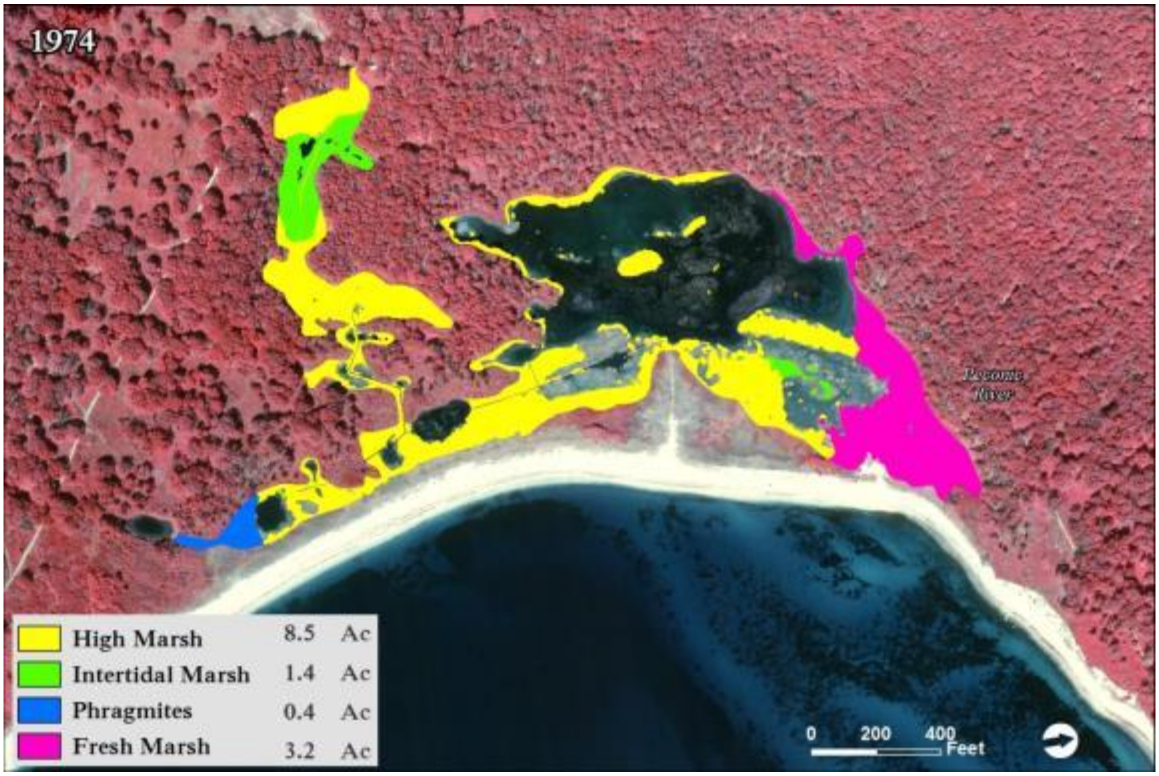


Figure 55: Plum Pond (Complex ID #126)
[See Page C9, Appendix I for Locator Map]



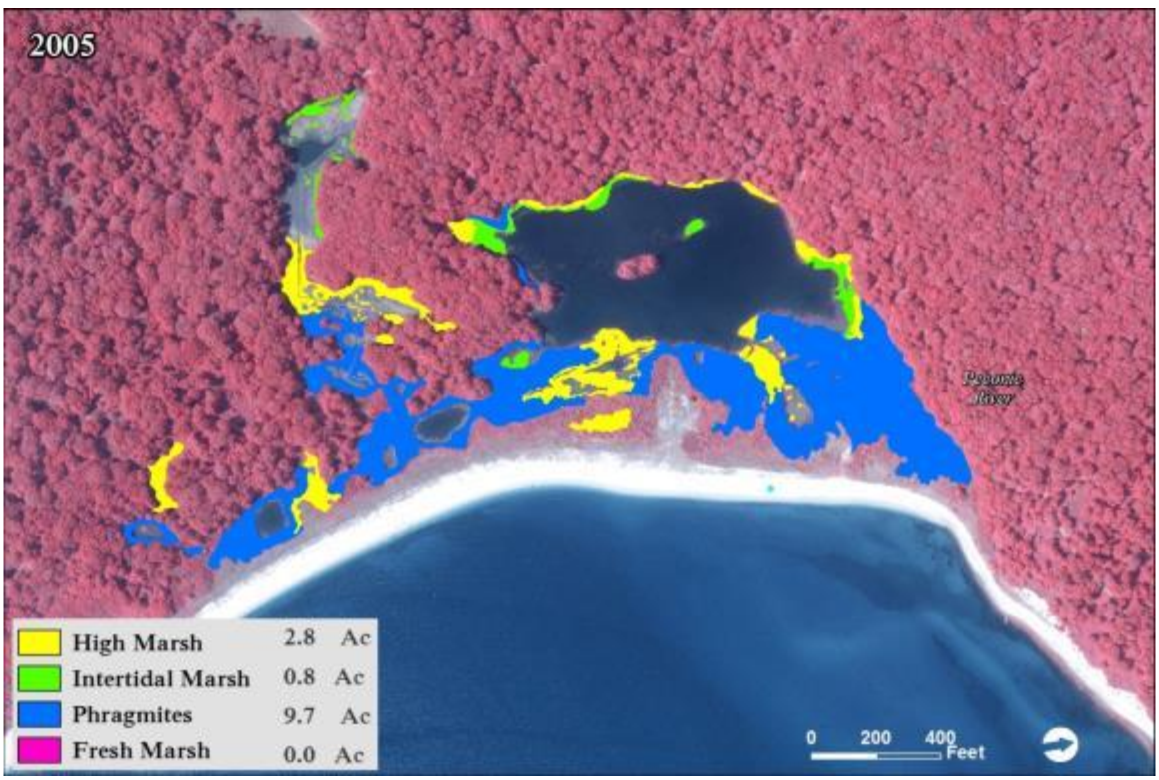
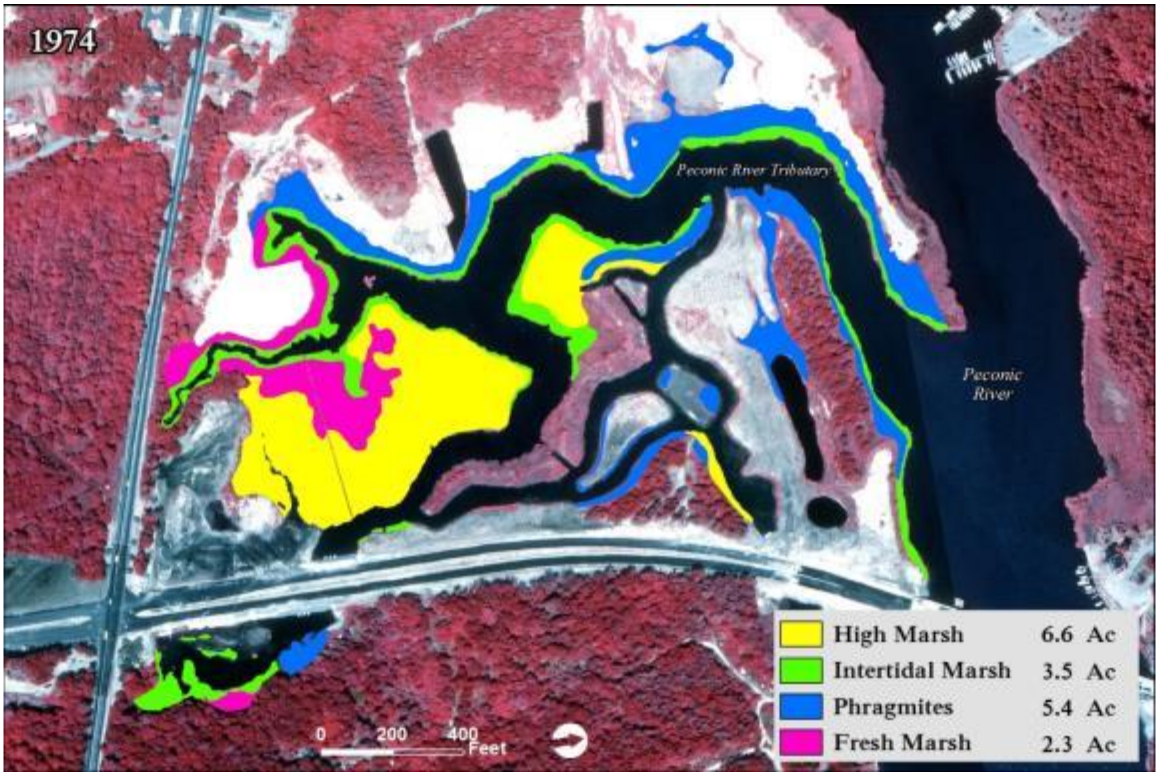


Figure 56: Peconic River Tributary (Complex ID #2)
[See Page D7, Appendix I for Locator Map]



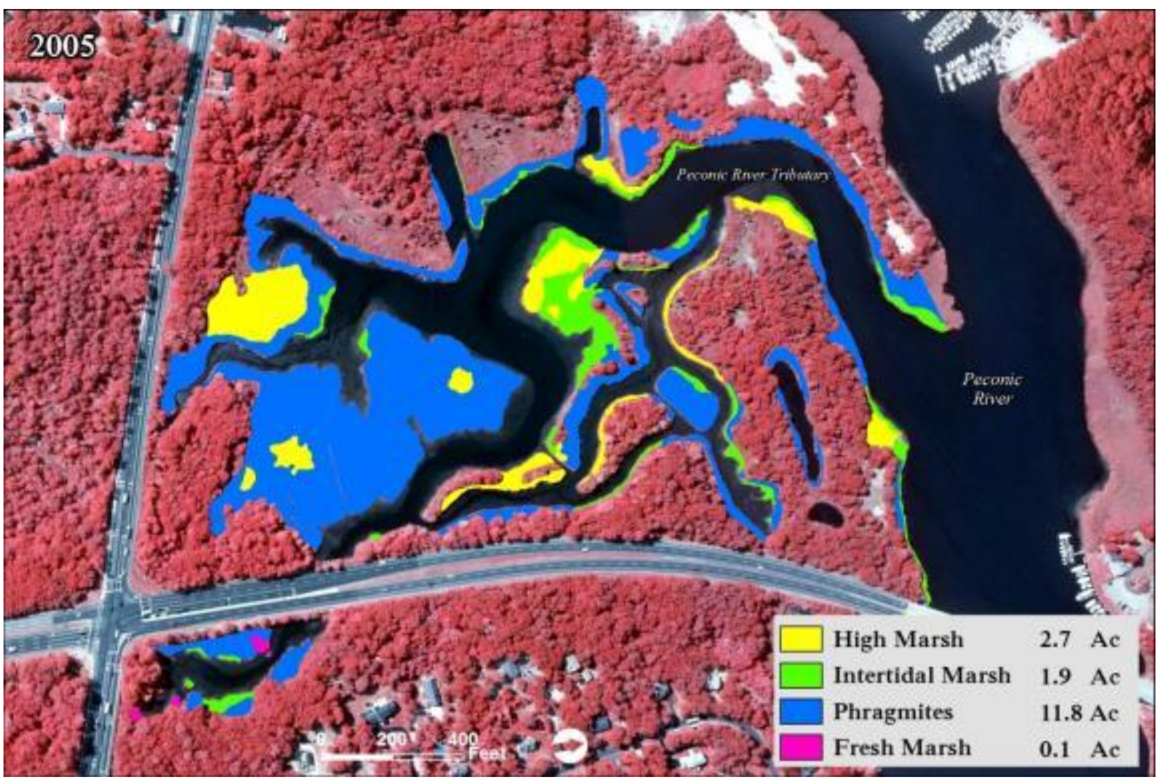
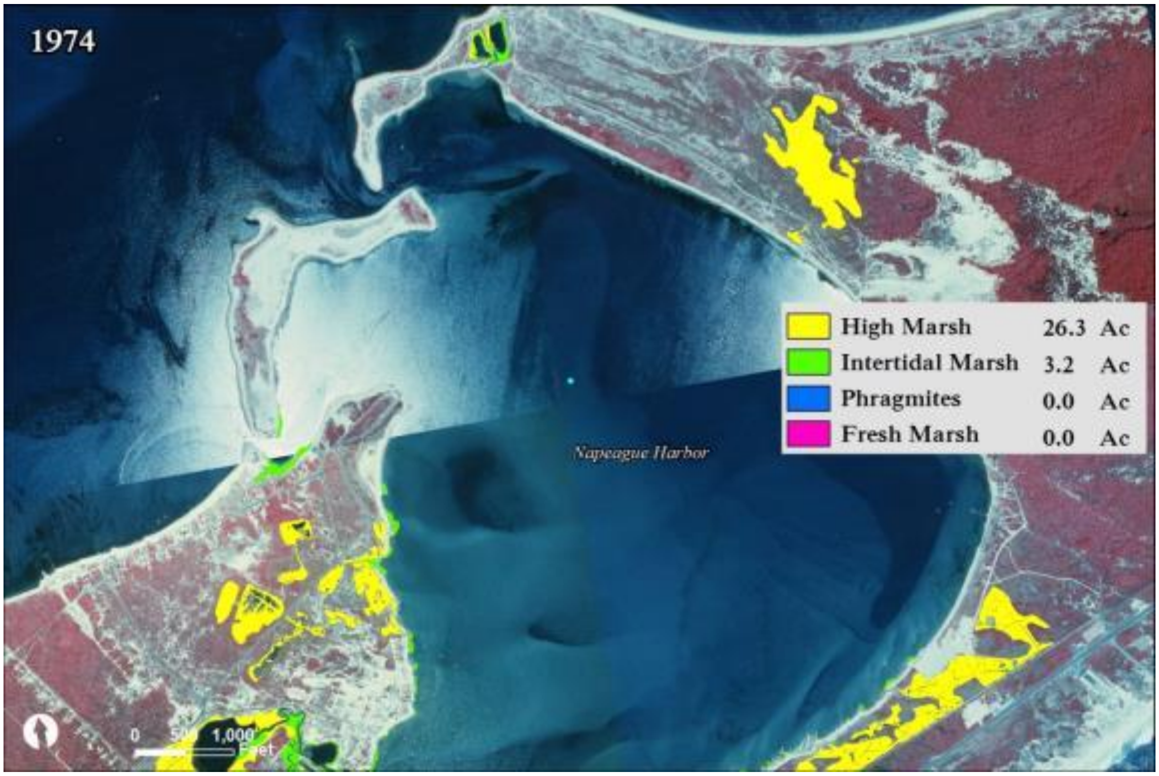


Figure 57: Napeague Harbor (Complex ID #153)
[See Page C10, Appendix I for Locator Map]



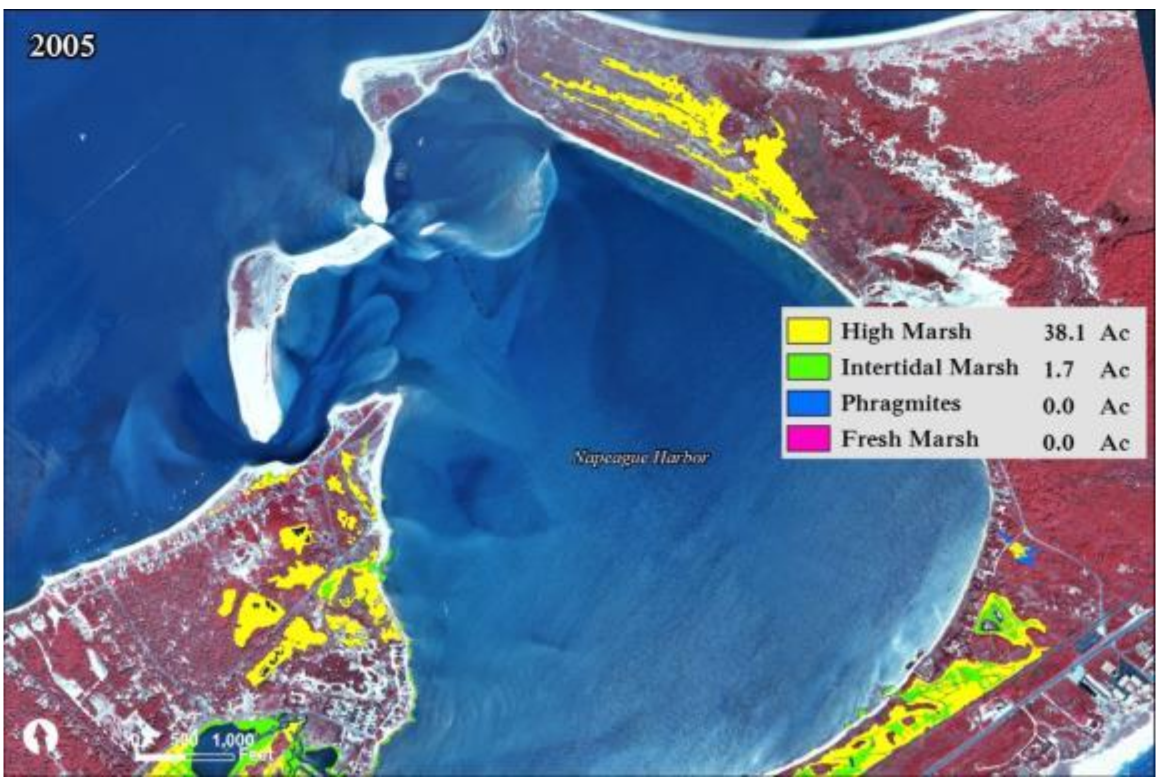


Figure 58: Cold Spring Pond West (Complex ID #204)

[See Page D8, Appendix I for Locator Map]

Table 43 summarizes the At-Risk marshes by town in the Peconic Estuary. An 'At-Risk' marsh was defined as one in which the change in vegetated marsh area exceeded 10 percent loss between 1974 to 2005. The trends analysis identified 86 'At-Risk' marshes complexes – out of a total of 159 – in the Peconic Estuary. Figure 59 provides the spatial distribution of 'At-Risk' marshes in the Peconic Estuary. Two data ranges were employed for the percent change in marsh area, i.e., '10 to 30 percent' and 'greater than 30%', for the 'At-Risk' marshes. The locations of 'Stable Marshes', i.e., those that sustained less than 10 percent loss in wetlands, are also mapped. 'Stable Marshes' appear to be situated in the lesser developed areas of the estuary. 'At-Risk' marshes are located throughout the estuary; however, clustering is apparent in the western portions of the estuary, particularly adjacent to more developed areas around Riverhead, Sag Harbor and along the north shore of Peconic Bay.

Figure 59: Peconic Estuary Wetland Complexes by Percent Change in Vegetated Marsh Area (1974-2005)

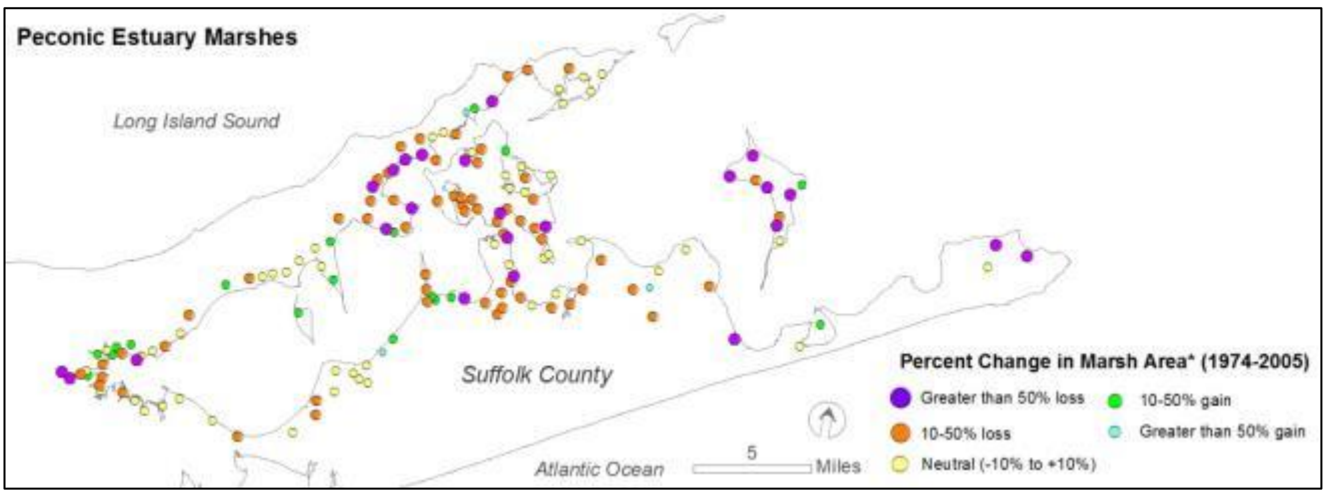


Table 43: At-Risk Wetland Complexes in the Peconic Estuary by Town

ID #	Wetland Complex	Town	1974 IM+HM (Acres)	2005 IM + HM (Acres)	Change in IM+HM (Acres)	Change in IM+HM (%)
114	Gardiner's Island Gales Pond	East Hampton	0.3	0.0	-0.3	-99.7
109	Gardiner's Island Bostwick Creek	East Hampton	27.3	4.4	-22.9	-83.8
150	Little Reed Pond	East Hampton	20.5	5.4	-15.1	-73.8
149	Oyster Pond	East Hampton	9.2	3.1	-6.1	-66.6
112	Gardiner's Island Boat Basin FC	East Hampton	1.7	0.6	-1.1	-65.7
155	Fresh Pond EH	East Hampton	7.3	3.1	-4.2	-57.3
110	Gardiner's Island Cherry Hill Pond	East Hampton	2.8	1.2	-1.6	-57.0
116	Gardiner's Island Tobaccolot Pond	East Hampton	19.0	9.4	-9.6	-50.4
113	Gardiner's Island Little Pond	East Hampton	10.1	5.6	-4.5	-44.2
111	Gardiner's Island Home Pond	East Hampton	20.0	13.7	-6.3	-31.4
163	Alewife Brook & Pond	East Hampton	32.3	22.2	-10.1	-31.3
167	Little Northwest Creek	East Hampton	47.0	33.3	-13.7	-29.1
160	Three Mile Harbor Hands Creek	East Hampton	9.1	6.8	-2.3	-25.1
156	Accabonac Harbor	East Hampton	260.9	214.4	-46.5	-17.8
164	NW Creek State Tidal Wetlands	East Hampton	28.8	24.3	-4.5	-15.6
165	Northwest Creek	East Hampton	162.4	137.2	-25.2	-15.5
161	Three Mile Harbor Inner Harbor	East Hampton	11.1	9.8	-1.3	-11.6
		Subtotal	669.8	494.6	-175.2	-26.2
76	Simmons Point	Riverhead	1.9	0.7	-1.2	-63.7
2	Peconic River Tributary	Riverhead	12.3	4.7	-7.7	-62.1
1	Peconic River	Riverhead	2.4	1.0	-1.4	-59.4
5	Colonel Island	Riverhead	3.2	2.1	-1.1	-33.8
82	Indian Island County Park	Riverhead	3.9	3.4	-0.6	-14.7
72	State Boat Marina	Riverhead	1.6	1.4	-0.2	-12.0
77	Bay Woods Drive	Riverhead	0.8	0.7	-0.1	-11.0
		Subtotal	26.1	13.9	-12.2	-46.8
148	Hay Beach Point	Shelter Island	1.9	0.0	-1.9	-100.0
126	Plum Pond	Shelter Island	13.1	3.7	-9.4	-71.9
133	Smith Cove Creek	Shelter Island	0.6	0.3	-0.3	-55.4
143	Chase Creek	Shelter Island	3.6	1.7	-1.9	-52.9
145	Gardiner's Creek	Shelter Island	9.8	5.2	-4.6	-47.2
119	Cedar Island Cove Marsh	Shelter Island	9.9	6.3	-3.6	-36.4
135	Dickerson Creek	Shelter Island	11.3	8.3	-3.0	-26.9
141	West Neck Creek Fred's Lane Tributary	Shelter Island	3.5	2.6	-0.9	-25.3
146	Dering Harbor Creek	Shelter Island	4.3	3.2	-1.0	-24.3
137	Montclair Colony Shoreline	Shelter Island	1.3	1.0	-0.3	-23.2
127	Bass Creek	Shelter Island	25.1	19.4	-5.7	-22.7
140	West Neck Creek Simpson Lane Tributary	Shelter Island	2.5	2.0	-0.5	-20.4
118	Coecles Harbor Shoreline IM	Shelter Island	15.7	12.8	-2.9	-18.6
136	Menantic Creek	Shelter Island	5.2	4.2	-0.9	-18.1
139	West Neck Creek Shoreline IM	Shelter Island	19.5	16.1	-3.4	-17.3
132	Miss Annie's Creek	Shelter Island	15.1	12.7	-2.4	-15.7
131	Log Cabin Creek	Shelter Island	3.8	3.2	-0.6	-15.1
147	Crab Creek	Shelter Island	12.8	10.9	-1.9	-14.6
128	Majors Harbor Marshes	Shelter Island	4.7	4.1	-0.6	-13.4

ID #	Wetland Complex	Town	1974 IM+HM (Acres)	2005 IM + HM (Acres)	Change in IM+HM (Acres)	Change in IM+HM (%)
134	South Ferry Marsh	Shelter Island	9.6	8.3	-1.3	-13.1
		Subtotal	173.1	126.0	-47.1	-27.2
181	Cedar Lane FC Wetland	Southampton	1.3	0.5	-0.8	-64.8
178	Actors Colony Road Marsh	Southampton	0.8	0.4	-0.4	-52.7
176	Fresh Pond (Sag Harbor)	Southampton	5.4	2.7	-2.7	-50.1
48	Noyack Jessup Neck North	Southampton	4.1	2.4	-1.7	-41.6
171	Middle Sag Harbor Cove	Southampton	13.0	8.8	-4.2	-32.3
179	Tyndal Point	Southampton	2.5	1.8	-0.7	-28.4
174	Upper Sag Harbor Cove	Southampton	7.7	5.6	-2.1	-26.8
9	Reeves Bay Islands	Southampton	4.4	3.3	-1.1	-25.7
8	Iron Point	Southampton	28.0	20.9	-7.1	-25.3
205	Shinnecock Canal (North of locks)	Southampton	0.1	0.1	0.0	-24.0
170	Lower Sag Harbor Cove	Southampton	15.7	12.2	-3.5	-22.5
173	Ligonee Brook	Southampton	2.9	2.3	-0.6	-20.3
175	Great Pond Creek	Southampton	15.1	12.3	-2.8	-18.7
11	Goose Creek (Flanders Bay)	Southampton	72.8	59.3	-13.4	-18.5
185	Noyack Morton NWR	Southampton	6.5	5.3	-1.1	-17.6
197	Little Sebonac Creek/Sebonac Island	Southampton	79.9	66.8	-13.1	-16.4
201	Bullhead Bay	Southampton	29.8	25.9	-4.0	-13.3
186	Noyack Jessup Neck	Southampton	7.1	6.2	-0.9	-12.7
169	Sag Harbor Shoreline	Southampton	1.0	0.8	-0.1	-12.1
		Subtotal	298.2	237.6	-60.6	-20.3
52	Paradise Point FC Wetland	Southold	0.5	0.0	-0.5	-95.9
56	Rambler Road Marsh	Southold	4.2	0.3	-3.9	-93.2
46	Debexidon Road Pond	Southold	1.3	0.4	-0.9	-65.8
43	Sage Blvd Boat Basins	Southold	1.5	0.5	-1.0	-65.3
49	Jockey Creek	Southold	3.9	1.6	-2.3	-60.1
35	Spring Pond	Southold	0.9	0.4	-0.5	-51.8
44	Mill Creek & Budd's Pond	Southold	3.5	1.7	-1.8	-51.5
48	Town Creek	Southold	2.9	1.5	-1.4	-47.8
38	Fanning Point	Southold	0.7	0.4	-0.3	-47.2
70	Brushs Creek	Southold	10.4	6.7	-3.7	-35.6
34	Dam Pond	Southold	15.6	10.1	-5.5	-35.1
67	Deep Hole Creek	Southold	13.3	8.9	-4.4	-33.1
58	Richmond Creek	Southold	36.5	24.7	-11.8	-32.4
47	Hippodrome Pond	Southold	5.2	3.9	-1.3	-25.3
50	Goose Creek (Southold)	Southold	23.8	17.9	-6.0	-25.1
53	Cedar Beach Point	Southold	36.7	27.9	-8.8	-24.0
57	Corey Creek	Southold	33.3	25.5	-7.9	-23.6
41	Arshomonaque Wetlands	Southold	22.2	17.0	-5.2	-23.3
42	Conkling Point	Southold	8.8	6.9	-1.9	-21.2
51	Harbor Lights Drive Wetland	Southold	3.0	2.4	-0.6	-20.4
31	Narrow River	Southold	17.8	14.8	-3.0	-16.9
33	Orient Harbor	Southold	36.3	30.6	-5.7	-15.6
45	Hashamomuck Pond	Southold	46.7	42.0	-4.7	-10.1
		Subtotal	328.8	246.0	-82.8	-25.2

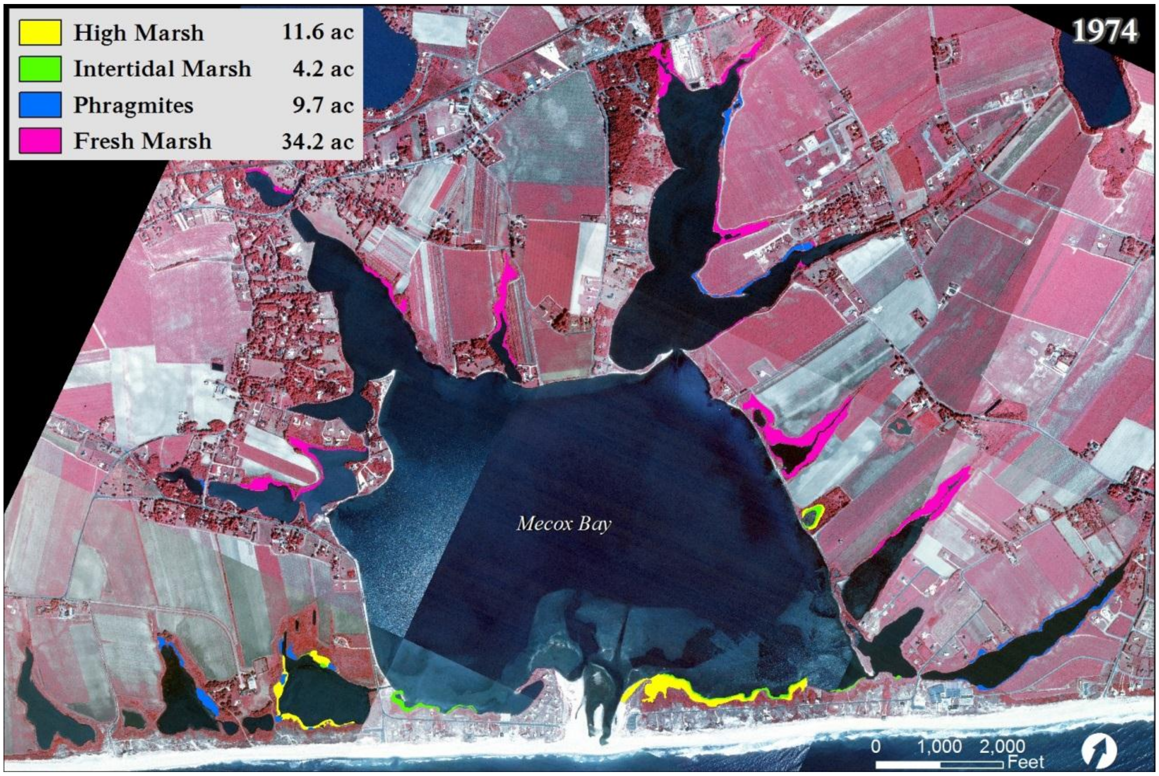
South Fork Ponds: Mecox Bay, Sagaponack Pond, and Georgica Pond

Mecox Bay (ID # 540), Sagaponack Pond (ID #541), and Georgica Pond (# 542) exhibited very large losses in native tidal wetlands between 1974 and 2008 as shown in Table 44. In 1974, these permanently flooded tidal ponds had 43.2 acres of coastal fresh marsh habitats located in their northern headwaters and small areas of intertidal and high marsh typically adjacent or proximal to the barrier beach. Due to extensive clearing, disturbance, and nutrient loading in the adjacent uplands, *Phragmites australis* stands in these coastal ponds have increased from 21.5 to 106.5 acres (395.7%) resulting in the near complete eradication of native coastal fresh marsh communities, as shown in Figure 60. The few areas of intertidal and high marshes present in these coastal ponds in 1974 have also been invaded by *Phragmites australis* resulting in -71.8 to -75.9% declines in these habitats. Percent loss of intertidal, high, and coastal fresh marsh between 1974 and 2005 was -98.7% for Mecox Bay, -59.6% for Georgica Pond, and -100.0% for Sagaponack Pond.

Table 44: Tidal Wetland Area Change (1974-2008) in Mecox Bay, Sagaponack Pond, and Georgica Pond

Wetland Type	1974 Wetland Area (acres)	2008 Wetland Area (acres)	Change (%)
Intertidal Marsh	5.8	1.4	-75.9
High Marsh	13.6	3.8	-71.8
Coastal Fresh Marsh	43.3	2.0	-95.3
Marsh Subtotal	62.7	7.2	-88.5
Phragmites australis	21.5	106.5	+395.7
Vegetated Area Total	84.2	113.8	+35.1

Figure 60: Mecox Bay (Complex ID #540)
[See Page D9, Appendix I for Locator Map]



Error Analysis

Two types of error were calculated for the tidal wetlands delineation. The first is classification error, which measures the initial mapping error with respect to groundtruthed 'test' points, and the second is relative error, which calculates the difference in wetland areas between the 1974 manual, photo-interpretation methodology and the computer-assisted classification approach applied to a set of 1974 color-infrared images.

Classification Error

Table 45 below summarizes the classification accuracy of the various species and feature types and for their tidal wetland classes. The classification accuracy provided in

is for the initial classification of the color-infrared images for the current year delineation, i.e., Year 2005 and Year 2008. Following the initial classification and vectorization of the classified imagery, the tidal wetland delineation were meticulously checked and manually corrected, where necessary, against high-resolution color-infrared imagery.

It is noted that the classification accuracy that was achieved for the Year 2005 and 2008 color-infrared images is exceptionally high for supervised classification, i.e., as compared with that typically reported in peer-reviewed literature. The relatively high classification accuracy is attributed to the project's extensive collection of groundtruthed training and test points which, in turn, resulted in a well-defined spectral library. The classification accuracy by class ranges from approximately 66% for the salt scrub class to 92.8% for intertidal marsh. The initial classification accuracy for both the native high marsh and intertidal marsh are relatively high for an image classification project owing to the numerous training points collected in the field and the relative ease with which these features can be extracted from color-infrared imagery. This is fortunate as the native high marsh and intertidal marsh comprise a large majority of the area of the tidal wetlands.

As expected given the complexity of the salt scrub, i.e., intermixing of species and variations in physical conditions in the uppermost reaches of the high marsh, its class classification accuracy is relatively low, i.e., only 66.9%. Accordingly, the largest share of manual tidal wetland boundary corrections was required for this class. Large areas of salt scrub are more likely to be found in wetland complexes of the South Shore and Peconic Estuaries compared to those in the Long Island Sound due to the less steep topography of the South Shore and Peconic Estuaries. As a result, the relatively low classification accuracy of salt scrub habitats disproportionately affects wetland complexes of the South Shore and Peconic Estuaries.

Table 45: Summary of initial classification accuracy for tidal wetland features and classes

Type	Correct	Incorrect	Total	% Accuracy
Native High Marsh				
Sp.pat/D.spic Sp. Dominant	6	0	6	100.0%
Spart. pat/Distic.spic 50/50	12	1	13	92.3%
Spartina patens	16	3	19	84.2%
Distichlis spicata	14	2	16	84.2%
Total	48	6	54	87.5%
Salt Scrub				
Juncus gerardii	8	2	10	80.0%
lva frutescens	17	6	23	73.9%
Phrag low-vigor	4	7	11	36.4%
Total	29	15	44	65.9%
Intertidal Marsh				
Spartina alt-short form	35	2	37	94.6%
Spartina alt w/rockweed	1	0	1	100.0%
Spartina alt-tall form	22	2	24	91.7%
Spartina alt/Distich spic 50/50	7	1	8	87.5%
	65	5	70	92.8%
Phragmites australis				
Phrag high-vigor	9	2	11	81.8%
Fresh Marsh				
Schoenoplectus sp.	4	1	5	80.0%
Typha angustifolia	1	0	1	100.0%
Total	5	1	6	83.3%
Unvegetated				
Salt panne	11	1	12	91.7%
Upland				
Ammophila breviligul	4	0	4	100.0%
Baccharis haliminfolia	13	2	15	86.7%
Morella pensylvanica	9	0	9	100.0%
Toxicondenron radica	3	1	4	75.0%
Panicum virgatum	6	0	6	100.0%
Total	35	3	38	92.1%

Relative Error

The discrepancy, or relative error, in wetland delineations is a comparison of the tidal wetland areas derived via the two methodologies for 25 randomly-chosen tiles as shown in Table 46.

This estimate – which is based on a random sample with probabilities proportional to size – depends on the variation of the newer measurement divided by its sampling probability. If the individual area measurements delineated by the previous, or older, 1974 methodology are denoted by A_{74old}, with a total acreage of T_{74old}, and if the measurements made using the newer, automated methodology are denoted as A_{74new}, then T_{74new} would be the total new wetland area.

Table 46: Summary of the area differences for the automated and manual delineation methodologies

	1974 Automated			1974 Manual			% Difference	
TW Tile	IM	HM	Total	IM	HM	Total	IM	HM
606-522	9.89	4.55	14.44	9.41	5.04	14.45	-5.11%	9.64%
610-494	239.87	20.33	260.20	237.64	22.92	260.57	-0.94%	11.31%
614-526	20.38	0.00	20.38	20.38	0.00	20.38	0.00%	0.00%
618-528	53.74	30.89	84.63	50.54	34.18	84.71	-6.34%	9.61%
620-492	20.36	4.68	25.04	20.16	4.89	25.04	-1.00%	4.24%
624-496	227.77	19.59	247.36	205.58	42.55	248.13	-10.79%	53.96%
624-528	20.12	9.76	29.88	18.84	11.19	30.03	-6.82%	12.84%
636-532	15.62	3.95	19.57	15.46	4.11	19.57	-1.07%	3.94%
638-500	60.74	171.38	232.12	47.67	185.12	232.79	-27.41%	7.42%
648-528	54.39	2.10	56.48	54.85	2.26	57.10	0.84%	7.11%
660-508	8.90	39.77	48.67	7.70	40.97	48.67	-15.50%	2.92%
672-508	15.20	43.33	58.54	13.60	45.20	58.79	-11.81%	4.12%
686-514	73.39	106.43	179.83	63.00	117.17	180.16	-16.50%	9.16%
690-516	37.22	11.59	48.81	38.68	10.13	48.81	3.78%	-14.35%
696-520	11.95	6.51	18.46	11.50	7.11	18.61	-3.94%	8.46%
704-530	38.96	41.25	80.21	36.43	44.26	80.69	-6.95%	6.80%
708-522	76.77	43.37	120.14	74.37	45.83	120.20	-3.23%	5.38%
708-530	4.99	21.97	26.96	5.02	16.94	21.96	0.70%	-29.67%
712-524	8.10	6.40	14.50	8.02	6.49	14.51	-0.99%	1.44%
716-550	5.98	9.26	15.24	5.72	9.70	15.42	-4.57%	4.56%
720-552	7.37	6.15	13.52	6.84	6.68	13.52	-7.79%	7.93%
724-548	19.11	4.61	23.72	18.55	5.18	23.72	-3.05%	10.95%
728-542	13.75	23.74	37.49	13.85	23.82	37.66	0.72%	0.32%
744-548	9.61	16.12	25.73	10.00	15.73	25.73	3.89%	-2.46%
748-572	2.21	1.40	3.61	2.23	1.42	3.65	0.80%	1.75%
Acreage	1056.40	649.12	1705.52	996.02	708.89	1704.90		
						Relative Error	-6.06%	8.43%

The sampling probabilities are A74old/T74old, so the estimate is simply the average of [A74new/(A74old/T74old)], which is the same as T74old × average [A74new/A74old] for the tiles sampled. Therefore, the discrepancy, or relative error, of the estimate depends on the variation in (A74new/A74old). This factor will be calculated for each tidal wetland class; the relative error will be calculated by subtracting this value from "1", or mathematically, 1 - (A74new/A74old).

There is a wide range of differences in high and low marsh area between the manual, photo-interpretation approach and the computer-assisted image classification, i.e., from -27.41% to +3.89 % for Intertidal Marsh delineations and from -29.67% to +53.96% for High Marsh delineations. However, a majority of percent difference values range from approximately +3% and -7% for the intertidal marsh comparison and from 0% to 8% for the high marsh. The relative error, as given by 1 - (A74new/A74old), is -6.06% for the intertidal marsh and +8.43% for the high marsh. These relative error values indicate that 1974 manual photo-interpretation approach underrepresented the intertidal marsh areas and overrepresented the high marsh. This finding is understandable given the inability of the photo-interpreters to delineate the relatively small intertidal marsh areas inside larger high marsh areas. This would result in a slightly larger intertidal marsh area and slightly smaller area for the high marsh for the computer-automated approach as compared with the photo-interpretation approach. There were no statistically significant differences in the percent difference values between the three major estuary systems (Long Island Sound, South Shore Estuary, and Peconic Estuary) for either intertidal marsh and high marsh classifications according to two tailed t-tests (i.e., all P values were greater than 0.05).

Future Approaches for Mapping Tidal Wetlands

This section considers potential approaches for future mapping of the tidal wetlands of Long Island that exceed the technical limitations of the multi-spectral (3-band) imagery and supervised classification methodology employed in this study. It is important to note, however, that despite many advances in data collection and image processing techniques, regional-scale wetland mapping remains one of the most problematic of all vegetation mapping exercises. In particular, variations in hydrologic regime, topography, nutrient loading and other stressors, induce significant variations in the spectral responses (i.e., differences in reflectance across the electromagnetic spectrum) of individual wetland species. Such variations are present at the local scale (i.e., individual marsh complex), but are magnified when mapping is required at regional levels wherein the potential for variations in the physical environment are even greater. For example, even a geographically limited area such as Long Island, sustains a varied array of marsh habitats, i.e., from the low-lying, predominantly intertidal marsh islands south of Hempstead, New York to the diverse intertidal, high and coastal fresh marshes of the Peconic Estuary. As a result of variations in physical parameters, the spectral signatures of different wetland species often overlap, in turn generating confusion and/or errors when attempting to differentiate between species (Tuxen et al., 2010).

As a response to the challenges of wetland mapping (i.e., in particular, computer-driven approaches at the regional scale), researchers have developed a variety of techniques to enhance mapping accuracy. These include hyper-spectral image acquisition and classification, object-oriented analysis, artificial neural networks and decision trees, to name a few. The following discussion briefly examines how such methods may be used either singularly or in combination to facilitate more accurate and rapid tidal wetland mapping for Long Island.

Historically, the first method used to map tidal wetlands at a regional scale entailed the manual, photo-interpretation of aerial imagery. To this end, the use of false color-infrared imagery was particularly advantageous. It was found that the red and infrared bands of the electromagnetic spectrum were particularly suited for effectively differentiating between a number of tidal wetland species. When combined with the visible green band of the electromagnetic spectrum, the red and near-infrared bands produced a 3-band, false-color image useful for readily distinguishing between the different marsh classes (i.e., inter tidal, high, salt scrub and coastal fresh marshes), upland species and non-vegetated areas (i.e., water, mud flats and salt pannes.) The manual photo-interpretation of such color-infrared imagery produced the official 1974 Tidal Wetland Maps of New York State.

The manual photo-interpretation approach can produce wetland mapping sufficient for defining the broader wetland classes and marsh extent. The limitations of this method are realized, for example, where tidal wetlands are comprised of multiple, intermixed patches of high and low marsh species and/or non-vegetated features (e.g., salt pannes) within a relatively small area. In such instances, manual photo-interpretation, or digitizing, of numerous polygons would be impractical while the resulting wetland area calculations would be underestimated or overestimated, depending on the wetland features.

At a minimum, the multi-spectral imagery and supervised classification methodology employed in this study provided higher resolution of marsh features compared with the previous 1974 manual delineations. (Indeed, image classification methods were applied to the 1974 imagery in order to extract pannes and water features from the 1974 tidal wetland mapping.) However, like the previous (1974) manual, photo-interpreted delineation, the computer-assisted classification performed under this project was also a time-consuming endeavor. This was owed primarily to the required processing of hundreds of color-infrared image tiles which covered the breadth of the Long Island study area. These images were comprised of 9-inch-by-9-inch color-infrared film frames on a roll which, as of necessity for digital image processing and classification, needed to be scanned and orthorectified. The orthorectified images were then normalized in order to apply a common spectral library of wetland and other species. Any future mapping efforts should, ideally, employ a digital camera or other digital sensors on either a satellite or airborne platform as opposed to color-infrared film. There are a number of reasons for this choice such as the following. Firstly, digital imagery would eliminate the need for scanning of film; the conversion from film (analog) to digital format always sustains some loss of information. Secondly, the use of digital imagery would prevent the edge effects, e.g., darkening, inherent in color-infrared image frames. In addition, the digital sensors that would be employed for future tidal wetland data acquisition would instead capture – for advantages described below.

Hyperspectral Data

The multi-spectral, color-infrared imagery employed in this project comprised only three spectral bands, i.e., one green, one red and one near-infrared. The reflectance values for these bands are, in effect, an average of the spectral responses across the approximate 0.4 to 2.5 nanometer (wavelength) portion of the electromagnetic spectrum. In reality, though, wetland species exhibit considerable variation in reflectance across even this small portion of the electromagnetic spectrum. The averaging of spectral reflectances – and thus the loss of spectral response information – was a primary reason for confusion between species when applying image classification to the multi-spectral imagery of this project.

Alternatively, hyperspectral imagery utilizes subdivisions of the 0.4 to 2.5 nanometer portion of the spectrum (i.e., several or more bands), thus allowing greater definition of a given species spectral fingerprint. In fact, hyper spectral imagery can record reflectances across dozens or even hundreds of narrow, continuous bands throughout the electromagnetic spectrum. Researchers have found, though, that reflectances across only several bands in the visible, near-infrared and short-wave infrared were optimal for mapping tidal wetland species (Adam et al., 2010). In particular, subdivisions of the red-edge and near-infrared portions of the spectrum were particularly useful for tidal wetland mapping as they demonstrated the greatest variation in spectral response among saltwater marsh species. For these reasons, it is recommended that future tidal wetland mapping initiative consider use of hyperspectral data acquisition and analysis techniques.

Secondary Landscape Attributes

Image classification techniques – which utilize either multi-spectral or hyperspectral data – may be enhanced through the use of secondary landscape attributes. Such data can serve as an overlay to aid the image classification algorithm in assigning the appropriate class or species to a given image pixel. Secondary landscape attributes may comprise, for example, the height of vegetation or soil type.

Data on vegetation height, in particular, would be highly useful in differentiating between certain wetland species on Long Island. For example, it was found that *Phragmites australis* and *Spartina alterniflora*, which although vary substantially in height, produce similar spectral responses under certain conditions. Specifically, the short form of *Spartina alterniflora* is spectrally confused with low-vigor *Phragmites australis* while the tall form of *Spartina* *alterniflora* is spectrally similar to the highest vigor form of *Phragmites*, i.e., within the context of multispectral imagery. However, in both of these situations, *Phragmites australis* is always taller than *Spartina alterniflora*. High-resolution elevation data for wetland species can be used in concert with multispectral imagery to improve classification accuracy. For example, a Connecticut River study conducted by Gilmore et al (2006) utilized LiDAR elevation data and multispectral imagery to map a marsh that was comprised primarily of *Spartina patens*, *Typha spp*. and *Spartina patens;* these plant species have distinct height differences which were used to more accurately differentiate between the wetland species. Such data, if available in the future, particularly for differentiating between certain life stages or environmental conditions of *Phragmites australis* and *Spartina alterniflora*, would help improve classification accuracy.

Other Methods

In addition to the use of hyperspectral data acquisition and analysis and secondary attributes for image classification, there are various other means to efficiently and accurately map tidal wetlands. These techniques include object-oriented analysis, artificial neural networks, fuzzy logic and decision tree analysis. Object-oriented analysis takes advantage of variations in plant texture and tone to identify wetland species; this approach has potential merit given the obvious textural variations wetland species in Long Island marshes. For example, *Phragmites australis* stands exhibit a fine, almost feathery texture while *Iva frutescens* patches appear clumpy with significant variations in one, i.e., light to dark pixels within a cluster. Artificial neural networks and fuzzy logic methods would potentially be useful for solving identification issues related to complex vegetation. Complex vegetation in Long Island marshes include mixed-class areas such as that which occur with *Iva frutescens* and low-vigor *Phragmites australis* near the upper limit of the high marsh. Decision tree analysis is a rule-based classifier for processing data at different scales; it would be especially useful in the future for integrating secondary attributes such as vegetation height, slope and soil type, provided such data were made available at sufficient resolution and geographic extent.

Summary

Given the wide range of tidal wetland mapping techniques presently available and for whose potential applicability and effectiveness to mapping Long Island's marshes is not fully known, it is recommended that a feasibility study be conducted prior to initiating any new tidal wetland mapping. Such a feasibility study would acquire pilot data sets and test the merit of various mapping approaches, especially those mentioned above. The development and testing of innovative wetland mapping techniques has historically been a pursuit of academic institutions and their researchers. Thus, the recommended feasibility study would necessarily be obliged to include experts in the field of remote sensing.

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