# 5 Suffolk County Wetlands Background Information

## 5.1 Introduction

CA determined that there are approximately 17,000 acres of vegetated tidal wetlands in Suffolk County, using a GIS interpretation of the National Wetlands Inventory (NWI) compiled by USFWS. Other accounts have found considerably more acreage (see Table 5-1), although the commonly quoted figure (which has no cited source) is 13,000 acres. Differences in the inventories listed in Table 5-1 stem from broadly sketched areas found in O'Connor and Terry (1972), and the inclusion of mudflats in the mapped definition of NYSDEC tidal wetlands. Map 5-1 (oversized, if print version; separate file, if electronic version) shows the agreed-upon names and locations of Suffolk County salt marshes, developed by CA, as agreed to by the participants of the Wetlands Subcommittee. This map will no doubt be improved on over time, as it is clear that local names and subdivisions of the marked salt marshes exist. Also, the map uses O'Connor and Terry as a base map, because that report named all of the areas it discussed (and so provided a basis for naming discrete salt marsh parcels); however, CA (and others) agree that maps such as the NWI (which does not name the salt marsh parcels) are more accurate in depicting the size and extent of salt marshes in the County.

Table 5-1. Tidal Marshes in Suffolk County (acres)

| | **NYSDEC**[1] | **O'Connor and Terry**[2] | **NWI**[3] | **"Tiner Report"**[4] |
|---|---|---|---|---|
| Peconic Estuary | 21,658 | 20,241 | 4,492 | 4,188 |
| South Shore | 26,550 | 18,579 | 9,772 | |
| North Shore | | 6,399 | 2,575 | |
| **Totals** | | **45,219** | **16,839** | |

1. As digitized in GIS format by NYSDEC (South Shore only) and NYSDOS (South Shore and Peconic Estuary only)
2. O'Conner and Terry (1972), as digitized in GIS format by Cashin Associates
3. Digital GIS format National Wetlands Inventory by USFWS, as interpreted by Cashin Associates
4. USFWS (1998) (Peconic Estuary only)

Fresh water wetlands are important potential mosquito habitats, as well. NYSDEC mapping of regulated freshwater wetlands adds to 18,084 acres. Since NYSDEC regulates wetlands of 12.6 acres (two hectares) or greater plus nominated wetlands of local significance, the sum of freshwater wetlands in Suffolk County is likely to be considerably greater. However, it should be noted that Long Islanders have been diligent in nominating "wetlands of local significance" to NYSDEC, and so the difference is less than it might otherwise be. The NWI also includes fresh water wetlands, but CA has not attempted to interpret the NWI code system to determine GIS coverages of fresh water wetlands by NWI. Mosquito management options for fresh water wetlands are currently very limited under the current NYSDEC regulations. Fresh water wetlands tend to be more diverse than salt marshes, and yet the local systems have had less systematic study than salt marshes have. This makes the discussion of fresh water wetlands less focused than the salt marsh discussion. This background section therefore emphasizes salt marshes over fresh water settings, which may be more appropriate since more active management of salt marshes is envisioned under the Long-Term Plan.

## 5.2 Introduction to Suffolk County Salt Marshes

The acreages listed in Table 5-1 are considerably less than was the case more than 100 years ago, and much less than the acreage of pre-Columbian wetlands. This is because wetlands have been filled for various reasons wherever people have settled (Mitsch and Gosselink, 2000). The environmental awakening of the 1970s led to laws and regulations limiting wetlands destruction, and New York State has a law specifying that there should be no net loss of wetlands (the Federal government has a similar Executive Order).

There are disputes regarding the general trends for salt marshes, nationwide and on Long Island. Locally, two agencies of New York State (NYSDOS and NYSDEC) disagree over whether “most” Long Island marshes are losing area. Both agree that Jamaica Bay wetlands are suffering from a rapid and general decay. NYSDEC has found substantial rates of loss in the western portions of the South Shore Estuary system, and in select marshes in the Peconic Estuary as well as along Long Island Sound. NYSDOS has not found such problems. As part of the Literature Search for the project, a report on wetlands losses was prepared. The report found that generally, in Suffolk County, the loss of wetlands due to construction, dredging, and dredge spoil disposal has largely ended due to the Tidal Wetlands Act. There needs be a distinction between wetlands loss and wetlands conversion; wetlands loss implies the loss of natural habitat and wetlands conversion means the change from one habitat type to another. The conversion of vegetated wetlands to other habitat types is a natural process and has been occurring for years. There is concern that an increase in the rate of sea level rise will increase the rate at which vegetated wetlands are converted into other kinds of habitats, which may not have the same functionalities that wetlands do. The opportunities for the landward advance of wetlands in conjunction with sea level rise are limited due to anthropogenic alterations of the landscape. There are areas where the rate of wetlands conversion is particularly rapid and dramatic (for example, Jamaica Bay). Salt marsh islands appear to be most susceptible to rapid conversion. There are a number of possible causes for rapid conversion, which are discussed in detail in the report (Cashin Associates, 2006).

There is general agreement that salt marshes and wetlands in general are threatened by factors associated with suburban development, including but not limited to:

- physical encroachment onto the marshes, by near-vicinity development;
- alterations of marsh hydrology, through coastline and bankside alterations;
- changes in area hydrology, because of the creation of impermeable surfaces causing additional runoff and decreased recharge;
- upland development, which causes changes to sedimentation patterns and chemical inputs to the marshes; and
- offshore impacts, such as dredging or beach nourishment, which impact natural currents and sedimentation patterns.

In addition, global forces such as sea level rise and general climate change can affect marshes (Mitsch and Gosselink, 2000).

### 5.3 Impacts of Mosquito Control Ditching on Salt Marshes

Ditches were installed in nearly all of Long Island's salt marshes, beginning in the 1920s (Cowan et al., 1986). This process was largely completed by public employment work crews in the 1930s (Glasgow, 1938), so that more than 95 percent of Suffolk County's salt marshes have been ditched. Locations of the 32 salt marsh fragments that were not ditched are shown in Figure 5-1 (identified by reviewing USGS Quad maps, and confirming a lack of ditching using 2001 six-inch resolution aerial photography).

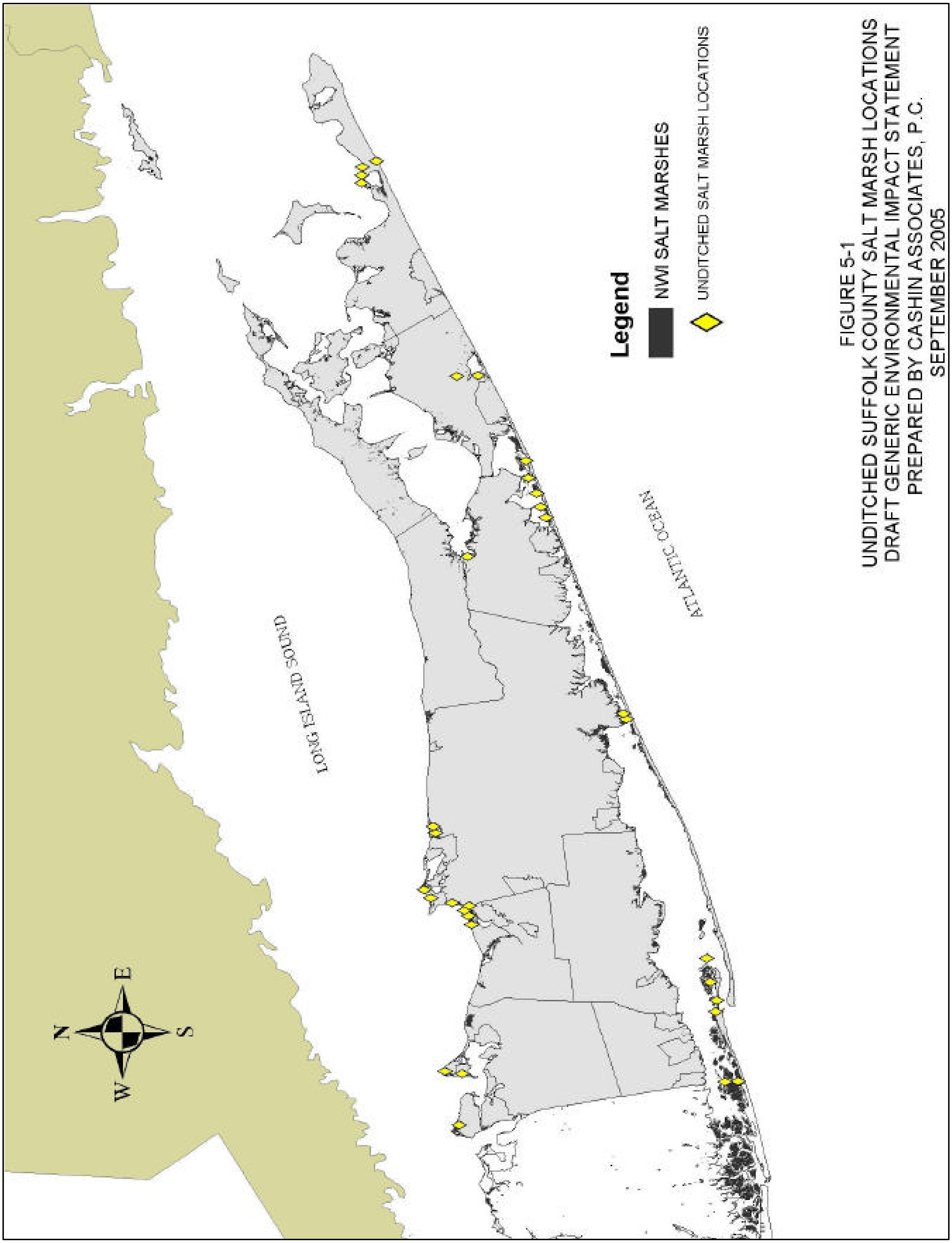


FIGURE 5-1
UNDITCHED SUFFOLK COUNTY SALT MARSH LOCATIONS
DRAFT GENERIC ENVIRONMENTAL IMPACT STATEMENT
PREPARED BY CASHIN ASSOCIATES, P.C.
SEPTEMBER 2005

Ditch construction and maintenance are sometimes characterized as traditional water management. Two kinds of constructed traditional water management were parallel ditching and grid ditching.

Parallel ditching is characterized by the ditches running in one direction, generally, from the upland to the shoreline, with relatively constant distances between the individual excavations. The ditches are usually constructed so as to be perpendicular to the shore or major creek. This creates panels of vegetation separated by the waterways (Bertness, 1999).

Grid ditching requires crosscutting the ditches, creating a grid of vegetation islands, and is sometimes called checkerboarding. Checkerboarding was used initially in larger marshes until it was found that parallel ditching was as effective as grid ditching, and required less maintenance (Richards, 1938).

Ditches were installed with steep sides, typically up to three feet deep and two to eight feet wide (Dale and Hulsman, 1990). On Long Island, three to four feet was the most common width (Taylor, 1938). Distances between ditches were commonly 100 to 300 feet. Soil permeability was supposed to determine the selected width, with less permeable soils requiring closer ditching (Dale and Hulsman, 1990). Ditching was intended to reduce mosquito breeding by draining standing water on the marshes (Dreyer and Niering, 1995), and also by allowing fish access to breeding areas (Richards, 1938); ditching may also reduce oviposition sites by reducing the area of the marsh where damp soils can be found (Dale and Hulsman, 1990).

The effectiveness of ditching as a mosquito reduction technique has been disputed (Nixon, 1982; Daiber, 1986), although most accounts agree that the combination of marsh filling and ditch construction in the early 20th Century did suppress mosquito populations sufficiently to allow for much greater development in many shoreline areas. This was particularly noted for the south shore of Long Island. Ditching was said to have resulted in

> the very ancient curse of Long Island [being] now well under control … the effectiveness of the ditches in controlling mosquitoes is so overwhelming … there seems to be no reason to oppose the ditching of all salt marshes.

(Taylor, 1938).

The overall impact of this ditching on the condition and health of salt marshes has been the subject of acrimonious disputes. Generally, ditching is said to have changed marshes in four ways (which sometimes intersect and overlap). They are:

1) reductions in the amount of mosquito breeding;
2) alterations of the salt water table found in the marsh peats
3) vegetation distribution changes
4) changes in use of the marsh by important species or species guilds

(Cashin Associates, 2004a)

The strength of opinions offered on both sides (e.g., Bourn and Cottam, 1950; Provost, 1977) suggests that the impacts do occur, but are not equally as great everywhere because of mitigating factors associated with particular marsh settings and ecologies (although see Nixon, 1980, who characterized the disputes as being supported by predispositions to find or not find impacts).

Ditching, as originally conceived, was intended to alter the hydrology of the marsh. There is some disagreement even about this. For the south shore of Long Island, for example, it was suggested that ditches do not "drain" the marsh, but instead relocate water from the marsh surface to the ditches (Taylor, 1938). This presumably addresses the low tidal range and persistence of water in the ditches of these marshes. In other settings, where greater tidal ranges mean the ditches often dry during low tides, it seems supportable to discuss ditches draining away water from the marsh (Dale and Hulsman, 1990).

Actual measurements of impacts or effects from this drained water are difficult to obtain, however. Anecdotal evidence is that ditching reduces the number and area of surface water bodies on the surface of the marsh (Bourn and Cottam, 1950), but even some who support the notion that ditches drain marshes did not find reductions in marsh ponds (Redfield, 1972), although the point is often disputed (Nixon, 1980). The difference was quantified for pairs of ditched and unditched marshes in New Jersey (Lathrop et al., 2000), and marshes at Gilgo on Jones Island (Merriam, 1983). At Gilgo, 16 percent open water was found for the unditched wetlands section, and 11 percent for the ditched areas. Many measures of water table impacts, however, find them either non-existent (Crosland, 1974) or limited to the near vicinity of the ditch or creek (Nuttle, 1988). The idea that ditches spaced 100 feet apart would drain a marsh has been called "optimistic" (Chapman, 1974). However, a more extensive survey of ditched and unditched marshes in New England (from Connecticut to Maine) found that unditched marshes had considerably more surface area in ponds than did ditched marshes, due to increased numbers of ponds (the size of ponds in both settings was similar). Tidal range and latitude were not found to be significant covariates, suggesting that it was the installation of the ditches that caused the difference (Adamowicz and Roman, 2005).

The ability of a ditch to remove surface water depends on the sediment type of the marsh, and the head pressure driving the water through the sediments. This is the basic mathematical description of water flow in porous media (the Darcy equation) (Freeze and Cherry, 1979). Necessarily, the greater the hydraulic conductivity of the marsh sediments, and the greater the head in the saline water table (best expressed as the vertical distance between the top of the water table in the marsh and the mean tide height), the more drainage of the water table there will be. It is not possible to undo ditching the marsh and determine what these relationships were prior to ditching. Most marsh peats have very low hydraulic conductivity. Where the difference in height between the water table and the mean tide is not very great, such as in the microtidal South Shore Estuary system of Long Island, drainage is likely to have been minimal, as measured by changes in water table elevation and in the distance effects can be determined into the panel. Where tide heights are greater, then the effects are likely to be greater, such as in the higher tidal amplitude areas of New England. Impacts may have occurred in the Huntington-Smithtown areas on the north shore of Long Island, where tide ranges can exceed seven feet. One anecdotal report was that dynamiting the marsh was considered in the 1940s in order to restore ponds in Crab Meadow, for example (H. Dam, Citizens Advisory Committee, 2004). It is difficult to determine, for mid-tidal range areas such as the Peconic Estuary, whether ditching changed marsh hydrology on theoretical grounds – and there are no good records to refer to for pre-ditching conditions.

This is very important, because most of the observed impacts of (or impacts attributed to) ditching stem from water table differences. Loss of surface water, for example, results in loss of habitat for muskrats (Bourn and Cottam, 1950) and diminished water fowl use of the marsh (Clarke et al., 1984). Other birds, for complex reasons, may not find the habitat as amenable, as was suggested for sharp-tailed sparrows (Post and Greenlaw, 1975). Changes in the water table may promote different vegetation on the marsh. Woody, upland-type vegetation are often found out on the marsh after ditch installation (Miller and Egler, 1950), and *Phragmites* invasion is believed to be fostered by ditching (Bart and Hartman, 2002). *Phragmites* colonization after ditching may be supported by drying out of the marsh in general, or it may be that *Phragmites* first colonizes drier areas along the ditches, and then spreads into the interior of panels, although the water table there is no lower or fresher than it was pre-ditching. There is ample evidence that *Phragmites* propagation by runner does not require the drier, less salty conditions that seed germination needs (Warren et al., 2001). The drier area along the ditch may be from drainage, or from the establishment of a berm along the ditch edge from poor spoils placement or the hypothetical settling out of particles as the tide wells up out of the ditch.

Ditching seems to have fostered *S. patens* expansion in some areas (Redfield, 1972). At Gilgo, an unditched area has a measurably higher *S. patens* to *S. alterniflora* area ratio than a ditched area did (Merriam, 1974). On Long Island’s south shore, where many of the marshes are “green lawns” of *S. patens*, ditching has been cited as a primary cause (Taylor, 1938). However, an analytical study of Long Island’s marshes found that, 30 or more years after ditching, the proportion of low marsh had increased at the expense of high marsh. The calculation was admittedly skewed by the filling of marshes, which was assumed to reduce the acreage of high marsh more than low marsh (O’Connor and Terry, 1972). Since the distinction between *S. alterniflora* zones and *S. patens* zones is generally established by the frequency of daily inundations (*S. alterniflora* can overcome the constant root zone anoxia that results from constant flooding) (Witje and Gallagher, 1996a; Witje and Gallagher, 1996b), and not by salinity differences (Pennings and Bertness, 1999), unless the installation of ditches caused changes in tidal inundation on top of the marsh by affecting the tidal prism, reports that ditching increased either high marsh or low marsh areas are not easy to explain.

In some areas, ditches may expand low marsh vegetation (*S. alterniflora*) by providing for higher salinity water deeper into the marsh, promoting waterlogged soils near the ditch sides (Miller and Egler, 1950). Another reason given for this impact is that ditches increase tidal penetration into and on top of the marsh (Kennish, 2001) (see just below). There may be other reasons than ditches for increases in *S. alterniflora* acreage, as there is some evidence that nutrient additions allow it to outcompete *S. patens* and therefore expand its range without further tidal inundation (Bertness et al., 2002).

Sometimes it has been asserted that ditching affects the tidal inundation of the marsh. It has been suggested that ditches absorb more of the tidal prism by increasing the depth below the marsh surface (Collins et al., 1986). This seems unlikely, given the immense volume of tidal inundations compared to the total volume found in the ditches. The depth of the tidal prism is controlled largely by the ability of the estuary (or estuary constriction) to transmit water. Therefore, the tidal range is dampened in the South Shore estuary because the narrow inlets cannot transmit enough water on the tidal cycle. The relative velocities of water flows can be altered, especially for tides that do not overtop the marsh surface, by changing the morphologies of the channels the tides pass through. This means adding or subtracting ditches from a channel network can affect whether sediments accumulate or not in the ditches (as a rule) (Zheng et al., 2003). It does seem possible that ditches carry salt water further into the marsh than would have occurred in their absence, but only for tides that are contained entirely within the ditches (Heusser et al., 1975). The absence or presence of ditches will not change the distance that tides penetrate the marsh when they overtop its surface.

Salt marshes, through marsh surface plant-sediment reactions, are often credited with water treatment capabilities. The accumulation of sediment in marshes generally indicates that nutrients and particle-associated contaminants will also accumulate in a marsh (Nixon, 1980). However, the effectiveness of the removal of contaminants and sequestration of various substances depends on various attributes of the marsh. Very roughly speaking, younger marshes that have more restricted connections to an estuary appear to accumulate materials more than older marshes with better estuarine connections (Valiela et al., 2000).

It should be understood that the greatest source of water to the surface of the marsh is tidal inundation. Therefore, the water most often treated by the marsh will be estuarine. This does not mean that salt marshes do not filter land-generated contaminants. This function is often listed as an important attribute of salt marshes. This concept seems to have been developed by considering how a constructed wastewater wetland works, in that it treats water flowing from the upland area towards the downslope area (Zdragas et al., 2002). However, especially on Long Island where nearly one-half of all ground water discharges as submarine flows, and run-off comprises at most only about five percent of stream flows (Buxton and Smolensky, 1999), recycling of off-shore estuarine water up onto the marsh is likely to be the most prevalent, albeit indirect, mechanism for salt marsh treatments of pollutants in some flows (see Montague et al., 1987). Ditches may reduce the time water spends on the reactive marsh surface, and so result in a decrease of the absorption of materials by the marsh. However, this can also be seen as beneficial, if the marsh is also serving as a positive exporter of valuable carbon, nutrients, and other needed material to the estuarine ecosystem (Odum et al., 1979; Odum, 2000). There is no direct evidence, especially on Long Island, that ditches by themselves serve as pathways for land-based pollutants to reach the estuary through some mechanism that short-circuits the treatment of storm water run-off (see Section 6, below for a discussion of an experiment conducted by the Long-Term Plan to test this hypothesis).

In some instances, storm water management systems have been designed so as to discharge directly to the marsh, or to ditches in the marsh. Generally, such connections are targeted for remediation through the USEPA Phase II storm water planning process (NYSDEC, 2001), although in some instances, as in Mastic Beach, it is difficult to determine what alternatives might exist.

Adding ditches to the marsh increases the perimeter areas of the marsh. In many cases, these kinds of “edge” habitats are valued, because they increase exchange between two different ecotones. For estuarine fish, for example, ditches (and other marsh channels) increase access to the productivity of the marsh (Whalley and Minello, 2002), and so would be habitat enhancements if the water quality in them is adequate.

The aesthetics of ditching are usually judged to be inferior. Salt marshes are generally perceived as being part of the natural, wilder world surrounding Long Island suburbia. The presence of geometrical structures across such environments is an unacceptable reminder of their managed nature to many people. Although there are many other shoreline vignettes where a mixture of natural and anthropogenic influences charms the visual senses (a lighthouse on a point, such as at Montauk Point, or a dock and boat array in a harbor, such as Northport Harbor, to name just two), ditches in a marsh generally are not among them.

The Literature Search (Book 9, Part 3) compiled a larger set of research findings on many of these questions (Cashin Associates, 2004a), although the key points are summarized above.

Judgements on these matters are affected, it is clear, by differences in weighing the values associated with salt marshes, and in determining whether a particular marsh is healthy. The underlying functions of a marsh, which affect ecological, ecosystem, and physical conditions, are given varying amounts of importance by agencies or others concerned with salt marshes. This weighting process determines the "values" of particular marshes for different stakeholders. Agreement on values is often difficult to obtain. A lack of accord on the values of a salt marsh then complicates determining the health of the marsh, as for many marsh health is a function of how the marsh values accord with some assessment of what they "should be" (Cashin Associates, 2005a).

## 5.4 Salt Marsh Functions, Values, and Health

The primary ecological functions provided by salt marshes are generally recognized as high productivity, food-web dynamics (energy transfer), and protective habitat. Primary production by salt-marsh grasses has long been known to be among the highest of any floral community in the world (Mitsch and Gosselink, 2000). In addition, it is now recognized that algal and phytoplankton production in salt marshes contributes significantly to overall rates of carbon fixation (Childers et al., 2000). Secondary production through fungal and microbial activity is another important process with regard to marsh/estuarine food-web dynamics (Newell, 2001; Newell, 2003). This complex trophic transfer is recognized as another important ecological contribution of salt marshes, particularly when considered with nutrient cycling and hydrological exchange in a wetland. Salt marshes also provide protective habitat for many species of birds, fish, and invertebrates. In particular salt marshes are recognized as essential habitat for migratory shorebird and water fowl species, as well as nursery grounds for finfish and shellfish which eventually make their home in the estuary (Mitsch and Gosselink, 2000). Owing to significant physical alterations to marshes and adjacent habitats, there is concern with respect to the declining ability of these systems to provide essential habitat for species.

Salt marshes play a critical role in estuarine food webs and in the pathways of nutrients to and through estuaries. Habitat structure affects the pathways and efficiency of transfer to higher level consumers in the food web. The source and amount of organic matter at the base of estuarine food webs are determined by a diversity of processes. For example, marshes can be used as an index of fish and wildlife production, in particular, for addressing nursery habitats of economically important fish and shellfish. From an ecological perspective there can be a strong connection between protozoans and fish, because the fish ultimately depend on the food-web pathway that is initiated by the lower trophic level of the protozoa (Hobbie, 2000). Continued study of marsh ecosystems and their relationship with adjacent habitats confirm a prominent role in trophic-energy transfers and ontogenetic contributions, but also increasingly reveal complexity and temporal variability in these linkages.

In addition to their biological roles, salt marshes display a variety of important physical functions. These functions include coastline protection, as well hydrological and geochemical roles (Mitsch and Gosselink, 2000). Coastline protection is generated by the physical buffer they present between the sea and the land. Important ongoing factors include coastal accretion (Allen, 2000), and mitigation of the impacts of flooding waters sediment qualities (Stolzenbach et al., 1992) and vegetation types (Leonard and Luther, 1995). The extent of protection that any given marsh can provide will depend on storm fetch, and its width and the composition of its vegetation. This makes generalizations regarding protection difficult, but it is safe to say that the absence of marshes where they formerly existed can only serve to exacerbate coastal flooding (Dale and Hulsman, 1990). Perhaps the most studied aspect of salt-marsh functions, and arguably the most controversial, is the role that these systems play in geochemical cycling and water quality. In general, estuarine wetlands are thought to contribute to the maintenance of water quality because accreting intertidal deposits are sinks for sediment and the metal and organic pollutants bound to them (Crooks and Turner 1999). In addition, early marsh studies (e.g., Teal, 1962) suggested that marshes were sinks for nutrients and sources for organic production. The export component of this idea has since been significantly revised, with most scientists agreeing that marshes do export some energy, but less than previously suggested and through much more diverse and complex trophic pathways. The nutrient uptake aspect remains unresolved, in large part reflecting the temporal and spatial diversity of marsh-system processes.

Not every marsh has equal share in the above functions, and the value of the system to a manager may depend on the importance of the functions to some desired endpoint. In addition, other factors can impact the valuation of a marsh. Growing environmental awareness in the 1960s helped cultivate broad public interest in the beauty of natural systems, including salt marshes.

What emerged was the first national-scale valuation of ecosystems based on aesthetic appeal, rather than solely the hard-currency of harvestable resources. Nixon (1980) notes:

> [Salt marshes] are important to me and to many other people who enjoy looking across the sweep and green openness of them, who like to walk out across them and observe their patterns of life and form. And these are not trivial reasons for maintaining that the marshes are important.

But aesthetic appeal is difficult to quantify, especially as expressed in the popular proverb that "beauty is in the eye of the beholder." In response to the continual demand for justifying environmental protection and stewardship, or more specifically the costs thereof, researchers frequently attempt to provide approaches or justifications in their publications. As an example, one such suggestion for salt marshes has been to assign higher value to those systems nearest to their natural state and to decrease the value of those that are "degraded" (i.e., farther from pristine) (Crooks and Turner 1999). "Degradation" in itself is a subjective notion, and given the incomplete understanding of marsh functions, somewhat suspect as a characterization of an ecosystem. Context may be extremely important; one could argue that any functions of a degraded marsh are of considerable value in an ecologically/environmentally stressed setting.

While salt marshes can be appreciated and valued for their beauty, or as to how they do or do not correspond to untouched natural settings, it remains to determine whether this is sufficient justification for the high cost of protection, preservation, and management of marsh ecosystems. Data, scientific evidence, and scholarly research clearly cannot sufficiently assess value to be relevant to legislative and budgetary decisions.

An emerging approach is that function must be combined with aesthetics, economics, and social perspective to generate values. This is the field of interest for ecological economics, with its focus on determining ecological and economic services provided by natural systems. This provides justifications for natural systems in terms of particular functions, and compares them to the artificial systems that would be required to replace them (if that were possible) (Balmford et al., 2002; Foley et al., 2005). Others try to extend the argument further, arguing that value is merely a product of a complex value system and valuation process (Daily et al., 2000). Value can thus be the result of an overriding framework in which people assign importance and necessity to their beliefs and actions – that is to say, culture, where community perceptions often differ from the sum of individual viewpoints because of collective social sensibilities. Exactly how these subjective and malleable concepts can be quantified is quite controversial, although some are not shy to attempt the deed (Costanza, 2000; Costanza, 2003).

A more expansive discussion of these issues is available in Cashin Associates (2005a).

In most instances, the practice of determining marsh health has relied on references to a preferred state for these ecosystems. Sometimes the comparison is relative, as when the Natural Heritage Program identified Long Island reference wetlands to which local sites could be compared (MacDonald and Edinger, 2000). Sometimes the comparisons can be absolute. Salt marsh health has been assessed as a concept, and related in particular to salt marsh settings in Suffolk County (Cashin Associates, 2004b). The conclusion was that the health of Suffolk County's salt marshes might be measured through a mixed process. Certain data (such as stem density, or percent invasive *Phragmites* vegetation) would be collected, and compared to values that represent "accepted" values. However, temporal trends in these and other values were also determined to be important arbiters of the health of the marshes, as marshes that do not achieve standard values might be deemed to be acceptable in terms of overall health if they are maintaining a given state.

The monitoring approach towards marsh health is given in Table 5-2.

Table 5-2. Proposed First-Order Indices for Marsh Health in Suffolk County (Cashin Associates, 2004b)

| **Health Indicator** | **Good Condition** | **Alert Status** |
|---|---|---|
| Marsh stability | Net loss of vegetated wetland <1% per year | Net loss of vegetated wetland >3% per year |
| Plant health (for *S. alterniflora* only – health of the high marsh presumably threatened by *Phragmites* invasion rather than vegetation loss as in the low marsh) | <5% of vegetated marsh with stem densities below 100/m$^2$<br>or<br>total below-ground biomass from 0-20 cm >3000 g/m$^2$ | >10% of vegetated marsh with stem densities below 100/m$^2$<br>or<br>total below-ground biomass from 0-20 cm <1500 g/m$^2$ |
| Invasive species | <30% *Phragmites* sp. | >50% *Phragmites* sp. |
| Resident finfish | Killifish group represented in most or all suitable habitats | Killifish group absent from >30% of suitable habitats |
| Species of Interest (e.g., marsh sparrows, terrapins, forb plants, others) | Stable population or consistent use of marsh by species of | No species of concern present or viable |

| | | |
|---|---|---|
| | special State or Federal status | |
| Temporal trends | Selected indicator does not trend negatively in 3 or more consecutive years | Selected indicator trends negatively in 3 or more consecutive years |
| Note: marsh characteristics between Good and Alert condition should be considered to be "Of Concern" and monitored closely | | |

## 5.5 Background Information on Salt Marsh Ecology

The salt marshes of the US east coast are highly productive, yet harsh environments. The diurnal tides are the primary influence on the development and function of the intertidal community in the marsh. The influx of saline waters produces a high osmotic gradient for plants to cope with. The upper intertidal zone is free from water during part of each day. When evapo-transpiration is high enough, interstitial water is removed from the soil at such a rate that soil is salinity may be higher than the salinity of the nearby waters (Pomeroy and Imberger, 1981).

Plants attempting to survive in these zones encounter a physiological perception of a scarcity of water. In this respect, the community has been compared to terrestrial salt deserts (Chapman, 1973; Wiegert and Freeman, 1990).

Marshes are documented as having low species diversity (Wiegert et al., 1981), perhaps a product of the stressful environment and relative to lack of niches resulting from the structural and productive dominance of *Spartina spp.* (Montague et al., 1981). The environmental extremes allow the limited number of adapted organisms to be relatively free from competing species and enemies. This lack of competition and low vegetation species diversity allow adapted organisms to occupy broader niches and become more abundant than would otherwise be possible (Teal, 1962; Ambrecht et al., 2004).

MacArthur (1965) theorized that community stability is increased whenever consumers in a low species diversity habitat have generalized diets. Omnivores should provide population stability in a low diversity habitat, because dominant species are not impacted by periodic oscillations in any one resource's availability. Since the major groups of salt marsh consumers are dominated by omnivores, the entire community is relatively stable in regard to shifts of resource availability (Kreeger and Newell, 2000).

Long Island salt marshes are on the southern border of what is known as the New England type of marsh (Redfield, 1965). They are characterized as being small, built on the glaciated coastal plain with marine sediment and marsh peat, with little transport of sediment from the uplands (Mitsch and Gosselink, 2000). Salt marshes of this type constitute less than two percent of the marsh area along the US Atlantic Coast (Reimold, 1977). Southern marshes are generally much larger, as a consequence of large supplies of mineral sediments provided by rivers that help to build the marshes outward (Frey and Basan, 1985).

The New England marsh typically contains three vegetative zones:

- a *Spartina alterniflora* low marsh
- a high marsh dominated by *S. patens,* with *Distichlis spicata*
- an upper border of *Juncus gerardi* with shrubby species at the territorial edge

(Nixon, 1982; Teal, 1986)

In contrast, southern marshes are dominated by *S. alterniflora*, with a stunted form of the grass covering the majority of the high marsh. This is the case as far south as Florida, where mangrove swamps gradually replace *Spartina spp.* marshes (Wiegert and Freeman, 1990).

### 5.5.1 Production

Research by Teal (1962) and Odum (1971) on vascular marsh plants led to the theory that salt marshes are among the most productive natural systems on Earth. Productivity in salt marshes varies greatly with latitude, with the highest values occurring in the south with longer growing seasons and higher solar input. There is approximately a threefold variation in productivity over the latitudes of the eastern US. There is a similar variation in productivity within any one marsh (Odum, 1988; Teal, 1986).

A high proportion of grass production is metabolized by the plants themselves. Plants inundated by salt water, as all plants are on the salt marsh, grow in an osmotically stressful situation, having to obtain carbon dioxide ($CO_2$) without losing too much water vapor through transpiration. An increase in respiration is necessary for the plant to maintain the higher osmotic gradient, lowering production (Chapman, 1973).

There are three major groups of primary producers in the salt marsh; the most visible, and usually considered to be the most productive in terms of total fixed carbon (C), is the rooted plant community. Algae, present on the marsh surface (microphytobenthos) and on the stems of the macrophytes (epiphytes), comprise a second set of producers. The free-floating phytoplankton of the tidal waters within the marsh is the third group. Approximately 75 percent of algal production occurs during ebb tide, with bare creek banks being the most productive areas (Pomeroy et al., 1981). Little production occurs under the dense plant cover found in the high marsh (Blum, 1968). Algal mats often cover unvegetated marsh surfaces in New England (Teal, 1986).

#### 5.5.1.1 Algae and Phytoplankton

Algae have a high turnover rate, compared to the macrophytes, and respond more rapidly to changing environmental factors that influence production, such as light, pH, salinity**,** and nutrients. Microalgae are readily eaten by benthic and suspension feeding animals. They are more nutritious and digestible then *Spartina* detritus (Kreeger and Newell, 2000). When algae-detritus feeders utilize algae, there is negligible lag between production and primary consumption, unlike the consumers of *Spartina* detritus and its associated microfauna (Teal, 1962). Biomass may be low relative to the vascular plant community, but this may be due to high grazing pressure from primary consumers, making the microphytobenthos the "secret garden" (MacIntyre et al., 1996; Miller et al., 1996).

Phytoplankton are not as important in the marsh ecosystem as algae, but because of their high nutritive value, are important resources for those consumers that can access them. Most phytoplankton in marshes are diatoms or dinoflagellates, with cell diameters so small (two to five millimeters [mm]) that only suspensions feeders can efficiently utilize them (Kreeger and Newell, 2000). Phytoplankton production occurs primarily in the adjacent estuary, but enters into the marsh ecosystem with the tides. Pomeroy et al (1981) found phytoplankton productivity in Sapelo Island marsh to be approximately 12 percent that of vascular plants.

#### 5.5.1.2 Rooted Plants

Wiegert et al. (1981) estimated that 80 percent of the primary production in the salt marsh is provided by rooted plants, with a 10 percent contribution by phytoplankton and 10 percent by benthic algae. Over half of the production of *Spartina* results in roots and rhizomes, which do not enter directly into the aboveground food web. If only aboveground production is considered, algal production values are reported to be 25 to 36 percent of the vascular plant production (Nixon, 1982; Wiegert et al, 1981). Rates may vary greatly among marsh systems and seasons. Other estimates range from less than 10 percent of vascular plant production (Sullivan and Moncreiff, 1988) to more than 100 percent (Zedler, 1980, in arid California settings).

The plant composition of a salt marsh is thought to be the result of a two-part process. Competitively superior plants dominate in physically mild habitats, relegating competitively inferior plants to physically harsh habitat areas. In salt marshes, the inferior competitor is *S. alterniflora*, which has been shown to thrive in the relatively physically benign upper marsh if competitors are removed (Bertness and Leonard, 1997). Thus, *S. alterniflora* is pushed to the physically stressful low marsh. The competitive dominants such as *S. patens* that inhabit the high marsh are unable to colonize the periodically flooded low marsh, as they cannot tolerate the physical stress. Bertness and Pennings (2000) believe that marsh plant zonation is influenced by climate. In northern, colder areas, the zonal limits on plant growth are set up by the tolerance of the plants to flooding. In southern sites, with high evaporation rates, especially at middle elevations, zonal limits are set by plant tolerance to increased salinities.

Characteristic of this vertical zonation is the vegetation pattern in the New England marsh, where the woody shrub *Iva frutescens* dominates the upper border and black rush (*Juncus gerardi*) is found at lower elevations along the upland fringe. Salt marsh hay (*S. patens*) is the characteristic plant of the irregularly flooded high marsh. *S. alterniflora* dominates the tidally-flooded low marsh, inundated usually twice each day (Niering and Warren, 1980).

General zonation of plants in the marsh can be described as being controlled by the interplay of two factors (Bertness and Pennings, 2000). The lower bound of a plant’s distribution is set by physical stress, where some combination of factors makes it impossible for one plant to thrive and yet allows the other to succeed. This physical stress may change depending on evaporation levels, so that flooding determines distributions in “New England” marshes, and soil salinity drives the distribution in southern marshes. The upper bound of a plant’s distribution is determined by competition, in that plants unable to thrive closer to the water are able to out produce those that can thrive there.

Bertness has been constructing more complicated explanations of the distribution of plants across the marsh over the past decade or so. He found that *S. alterniflora* can be found in the high marsh, but only following disturbances (such as wrack smothering the pre-existing plants) and is soon displaced by *S. patens* and other high marsh plants (which cannot grow in the low marsh) (Bertness and Ellison, 1987). General zonation between *S. alterniflora* and *S. patens* was hypothesized to occur because of the interplay between several factors. One is that *S. patens* cannot oxygenate anoxic sediments, and so will not colonize bare patches in such environments. Secondly, *S. alterniflora*, in larger aggregations, can oxygenate such soils (but lone plants or small clumps cannot, or cannot do it well, and so are stunted). Finally, although *S. alterniflora* can grow in parts of the marsh where sediments are generally well oxygenated, it is displaced in those areas by *S. patens* after several seasons. Therefore, *S. patens* out competes *S. alterniflora*, but *S. alterniflora* can grow in more stressful environments where *S. patens* cannot (Bertness, 1991). Fertilization by nitrogen from groundwater upwelling can alter the natural competitive arrangement of marsh plants (see, also, Levine et al., 1998). In fact, Pennings et al. (2002) described impacts from nutrient additions as being independent of specific marsh characteristics, in that *S. alterniflora* expansion, at the expense of high marsh plants, was apparently universal wherever nutrient inputs to a marsh are increased. Theodose and Roths (1999) might describe this depiction as a bit simplistic, as they found the zonation of plants in the high marsh to be a complicated interrelationship between nutrient availability (both nitrogen and phosphorus), and the actual absorption of nitrate by specific plants.

The low marsh is the area flooded by all tides under normal conditions (Teal, 1986). In this zone, for the east coast of the US, the macrophyte community is typically a monoculture of *S. alterniflora*. Here the soil is usually muddy and saturated with water. This generally creates anoxic sediment conditions that can limit the ability of plants to colonize the substrate (Howes et al., 1981). *S. alterniflora* has aerenchyma tissue that supplies oxygen to the roots, thus aerating the soil in the near vicinity of its roots. The presence of already established soil oxygenating plants creates a less stressful environment, leading to denser growth and higher productivity (Witje and Gallagher, 1996a; Witje and Gallagher, 1996b).

*S. alterniflora* occurs in two forms, categorized as tall and short. Tall forms are found along banks and tidal creeks, and have thick, widely spaced stems. The short form is found in the remaining low marsh area and, in the south, throughout the high marsh. It is characterized by thinner, more densely packed stems of shorter stature. This disparity in growth is mainly a function of the environmental conditions under which the plants develop (Mendelssohn, 1979; Wiegert and Freeman, 1990).

Ideal factors for growth along creek banks include the lack of competition for light and space, and a plentiful water supply. Adequate minor nutrients and potassium are present in the tidal waters, while major nutrients are available in the creek side mud. With these inputs, the tall form of *S. alterniflora* is as productive as any naturally growing plant (Teal, 1986). Odum (2000) believed that the energy inputs represented by the twice-daily tidal flushing were the ultimate sources of the high productivity. A major portion of the low marsh productivity results in the formation of roots and rhizomes. The proportion of aboveground and belowground growth varies with the overall productivity of the area (Teal, 1986). In the most productive zones (tall *S. alterniflora*), nearly equal biomass is produced above and below the ground. In contrast, *Spartina* (generally) in areas of lower productivity directs considerably more energy to belowground growth. This is the case in both northern and southern marshes. This direction of production may be seasonal as well, with rhizomes storing energy as winter approaches to sustain rapid growth in the spring (Schubauer and Hokinson, 1984).

Steever et al. (1976) associated 90 percent of the variation in productivity in different Long Island salt marshes with tidal range, with higher tidal ranges corresponding to greater productivity. They also found this to be the case generally for the east coast. Evidently, tidal flux correlates with increased productivity, probably through the mechanisms of nutrient supply, waste removal, and salinity control (Teal, 1986).

Nixon (1982) considers the definition of a New England high marsh to be taxonomic. The high marsh includes the area dominated by salt marsh hay (*S. patens*) and spike grass (*D. spicata*) as well as its upland border, inhabited by black grass (*J. gerardi*) and switch grass (*Panicum virgatum*). At the upper elevations, the high marsh reaches a transition zone on the edge of the upland habitat. This fringe is dominated by shrubby species such as marsh elder (*Iva fructescens*) and groundsel bush (*Baccharis halimifolia*), along with *Phragmites australis* (*Phragmites*) and cattail (*Typha spp.*) where there is a fresh water influence. Nixon (1982) quantified the belowground production of roots and rhizomes as being four times the aboveground value. This dense subterranean growth drives the vertical growth of the marsh through its volume and sediment trapping ability. Maintenance of high marsh elevation prevents inundation by tides and so perpetuates the environmental conditions that foster the particular plants found there (Redfield, 1965; Nixon, 1982).

The number of plant species in a marsh increases with elevation, with greatest variety in the marsh border (Miller and Egler, 1950). Besides the marsh hay and spike grass, the high marsh is home to sea lavender (*Limonium carolinianum*), seaside plantago (*Plantago juncoides*), slender salt marsh aster (*Aster tenuifolius*), seaside goldenrod (*Solidago sempervirens*), salt bush (*Atriplex patula*), sealite (*Suaeda linearis*), and glassworts (*Salicornia spp.*) (Nixon, 1982).

Salt marshes of the New England type constitute less than two percent of the marshes along the US Atlantic coast and the high marsh may amount to only 25 to at most 50 percent of that amount (Nixon, 1982). The portion of marsh covered by high marsh species may be decreasing due to losses to development. In addition, nitrogen loading may lead to intrusions of *S. alterniflora* into the *S. patens/Distichlis* zone. Apparently, adding nitrogen tilts the competitive balance in favor of salt marsh cordgrass (Bertness et al., 2002).

Nixon (1982) noted that *S. patens* forms a more tussocky, uneven surface than *S. alterniflora*, and that "rotten spots" may form under high marsh cowlicks. Sediment deposition on the high marsh tends to keep pace or slightly exceed sea level increases (Redfield, 1965).

While *S. patens* largely dominates the New England high marsh, it becomes relatively uncommon in southern marshes. In fact, the ratio of high marsh to low marsh generally decreases with latitude, falling to 0.3 in Georgia (Spinner, 1969). Intra-marsh salinity profiles vary with latitude, and are driven largely by climate (Pennings and Bertness, 1999). In a New England marsh, salinity usually decreases from the waters edge to the terrestrial border. In contrast, with greater evapo-transpiration rates in the south, hypersaline soil is typically found at mid marsh elevations, even in undisturbed stands of vegetation (Wiegert and Freeman, 1990). These areas are usually not affected by frequent tidal inundation or significant freshwater runoff from the uplands. In low spots or areas of poor soil drainage, evaporation increases interstitial salinities to levels where no vascular plants can survive. These salt pannes (salt barrens) may have a thin covering film of blue-green algae, and are often ringed by succulent *Salicornia spp.*

Pannes that form on the high marsh in New England marshes are usually formed by different mechanisms, such as smothering of vegetation by wrack (Nixon, 1982).

#### 5.5.1.3 Phragmites

*Phragmites australis* (Cav.) Trin. ex Steudel (formerly *Phragmites communis*, simply called *Phragmites*) has been present in North America for at least 40,000 years (Salstonstall, 2002). It has recently become more aggressive and invasive. Salstonstall has determined that the more aggressive strain is the same genotype as is found in Europe, and therefore this is a non-native, invasive strain. It has the ability to grow more than four m in height with a dense underground rhizome system.

Where and when *Phragmites* became invasive an, and, therefore, a problem, is often disputed. Redfield (1972) found localized *Phragmites* presence at the upland edges of a ditched marsh, where freshwater inputs were notable. In 1984, Clarke et al. found a Massachusetts marsh was being encroached upon by *Typhus* (cattails) from the freshwater edges, and did not mention *Phragmites*. Orson et al. (1987) found *Phragmites* in cores ranging back thousands of years in a Connecticut marsh, but noted that there are “recent” increasing monospecific stands of *Phragmites* in the marsh. A more generalized study by Orson (1999) of cores from several Connecticut marshes, and one each in Rhode Island and Massachusetts, found *Phragmites* dating back thousands of years, but only in association with marsh edge or brackish marsh plants.

Monospecific stands and/or associations with *Spartina spp*. are mostly not discussed until 50 to 100 years ago. Generally, northeastern US salt marshes are now noted as being heavily invaded by *Phragmites* (Lathrop et al., 2003). However, there are also data suggesting not all invasive events are caused by European-stock *Phragmites* (Lynch and Salstonstall, 2002).

On Long Island, Lamont (1997) noted that *Phragmites* was collected in Jamaica Bay in 1864, and from Wading River in 1872. Harper (1918) reported *Phragmites* upland from *S. patens* at a marsh near Whitestone. At Cold Spring Harbor, it is clear that the salt marsh was free of *Phragmites* as late as 1920; however, by 1997, the high marsh was monoclonal *Phragmites*. Similarly the spread of *Phragmites* on the East End of Long Island can be traced from Orient in 1900 to Cutchogue by 1918 and the South Fork by 1920 (Lamont, 1997). Udell et al. (1969) did not mention *Phragmites* in a discussion of primary production in Hempstead Bay (albeit, only the four most common marsh plants were discussed). O’Connor and Terry (1972) generally found that *Phragmites* was restricted to areas impacted by dredge spoils or without much salt water influence, although south shore areas with higher salinities and *Phragmites* presence were noted. Cademartori (2000), in an unpublished thesis, found *Phragmites* increases in Stony Brook Harbor from the 1930s through 1999. She linked increased fresh water inputs from upland drainage to the increases in *Phragmites* abundance.

According to Penny (1977), local residents linked *Phragmites* expansion on the East End of Long Island to the Hurricane of 1938. Support for this theory comes from Bart and Hartman (2003), who thought storms could upend natural salinities enough to allow a *Phragmites* foothold to develop. Dreyer and Niering (1995) specify that *Phragmites* invasions are due to reductions in tidal flooding. Burdick and Konisky (2003) suggest the reaction of *Phragmites* to the stresses brought about by salt water flooding are not well-described, and so it is not clear whether or not there are fundamental reasons that restrict *Phragmites* from saltier waters. Many others note that salinities in excess of 18 to 20 ppt seem to inhibit or reduce *Phragmites* growth (Marks et al. 1994; Meyerson et al., 2000; Bart and Hartman, 2002; Chambers et al., 2003; Havens et al., 2003; Lathrop et al., 2003). Witje and Gallagher (1996a, 1996b) found that *S. alterniflora* seeds could germinate at higher salinities than could *Phragmites* seeds, and that the *S. alterniflora* seeds grew rapidly, especially under anoxic conditions that *Phragmites* did not tolerate. They suggested this ability to tolerate more stressful conditions may establish initial zonations between the plants on marshes. Havens et al. (2003) even suggest constructing subtidal ditches to convey saltier water into *Phragmites* stands to reduce their expansion. Hellings and Gallagher (1992) found that the combination of flooded conditions and 18 ppt salinity can prevent rhizomes from budding. Bart and Hartman (2003) suggested that the burial of larger rhizomes (perhaps through ditch maintenance, storms, or even duck blind construction) in well-drained areas such as ditch or creek banks is the way that *Phragmites* might overcome otherwise hypersaline marsh conditions.

The spread of *Phragmites* in a Connecticut salt marsh, noted by Orson et al. (1987), was attributed to uplands development (citing Roman et al., 1984). Bertness et al. (2000) also found that shoreline development precipitated *Phragmites* expansion (there was a positive, statistically significant correlation between marshes with developed fringes and *Phragmites* invasion of the marsh), and said the mechanism for the change was unbalanced competition due to nitrate inputs.

In 2004, Bertness et al. modified this position slightly, suggesting that development of the marsh fringe reduced absorption and/or infiltration of precipitation, and that increased runoff over the marsh surface caused *Phragmites* expansion, through a lowering of salinities and increased inputs of nitrate. Meyerson et al. (2000) point to nitrogen inputs as the initiating event causing *Phragmites* expansion. Decreases in sulfide concentration were shown to allow *Phragmites* to better absorb ammonium and so meet the nitrogen conditions necessary for it to out compete *S. alterniflora* (Chambers et al., 1998). *Phragmites* appears to alter nitrogen flows within a marsh, increasing the amounts found in standing vegetation, which may change the nitrogen balance for an invaded marsh (Windham and Meyerson, 2003). Marks et al. (1994) summarized the conditions resulting in the spread of *Phragmites* as disturbances and stresses, such as pollution, hydrologic changes, dredging, increases in sedimentation and/or soil salinity (from fresh to brackish) and/or nitrate concentrations, all abetted by the potentially invasive European genotype. Another summary of the requirements for *Phragmites* expansion included salinity less than 10 parts per thousand, low sulfide concentrations, and inundation frequencies less than 10 percent (measured in terms of number of times flooded per number of high tides) (Chambers et al., 2003). These changes may impact only a small area on a particular marsh, allowing only a few plants to expand their range, and then this initial foothold can allow for expansion by *Phragmites* into otherwise less inviting habitat and eventual domination of the entire habitat. On the other hand, Burdick and Konisky (2003), although agreeing that greater drainage is important and nitrogen inputs may play a role, suggested that filling and road-building are greater contributors to *Phragmites* invasions, by compacting soils and increasing groundwater inflows (resulting in decreased salinities).

The rapid vertical and horizontal clonal growth of *Phragmites* allows it to overgrow other wetland plants by physical displacement. Its tall, dense aboveground growth alters environmental conditions such as light, space, and temperature (Meyerson et al., 2000). It has been shown to invade areas periodically flooded by full strength seawater through clonal integration (Amsberry et al, 2000), and by accessing freshwater lenses via deep taproots (Meyerson et al, 2000).

*Phragmites* is not consumed to any great extent by wildlife, nor is it considered an important nesting habitat for most marsh-resident birds (Buchsbaum et al., 1998). Wainright et al. (2000)

did find that *Phragmites* may be contributing to the mummichog (*Fundulus heteroclitus*) food chain, and so to marsh food webs generally.

#### 5.5.1.4 Role of Marsh Production in the Regional Ecology

Odum (1961) used the term "outwelling" to describe the movement of nutrients and energy from shorelines to estuaries and coastal waters, as a parallel process to the delivery of nutrient by upwelling. He envisioned rivers and coastal marshes as being major contributors of allochthonous materials to support coastal productivity in the same way that deep waters enriched in nutrients can enrich particular coastal areas. Subsequent publications bolstering this hypothesis contained little in the way of data to support the selection of salt marshes as sources of nutrients and C (Odum and de la Cruz, 1967; Pomeroy et al, 1967). Nonetheless the idea that salt marshes act as productivity pumps that feed adjacent waters became dogma (Nixon, 1980).

Nixon's 1980 review of marsh-estuarine interaction studies determined that most generalized salt marsh scientific theory was grounded not in data, but in speculation. Nixon concluded that tidal marshes appear to export organic C, but that the available data available did not substantiate the outwelling hypothesis as defined at the time.

Odum (2000) has radically modified the hypothesis statement, in any case. Rather than being viewed as steady state exporters of productivity, marshes may export through episodic or "pulsing" events that are associated with heavy rainfall or unusually high tides. The degree of export appears to be a function of individual marsh productivity, maturity, tidal amplitude, and geomorphology. A mature marsh has filled its basin to the high tide level and acts as a sediment sink only in relation to the gradually rising sea level (Teal 1986). This is the case with the Great Sippewissett Marsh in Massachusetts, which exports organic C to Buzzards Bay. In contrast, a young marsh, such as Flax Pond on Long Island, may show a net import of organic C from surrounding waters (Valiela, 1982).

The physical structure of a marsh system affects the export/import role. Odum (1979) classified marshes into three types according to their flow and tidal exchange characteristics.

1) Where tidal exchange occurs through a restricted or long and narrow channel, export of production (if any) would be lessened.

2) Marshes located in restricted basins or basins newly opened to the sea that are not importers of sediment may only export to the adjacent basin.
3) Outwelling (steady export of material), at least to nearby waters, is most likely to occur in areas where mature, productive marshes are extensive, and are open to the sea, if tidal amplitudes sufficient to provide the energy to drive the export occur. These are the areas that Odum (2000) now terms "outwelling hot spots."

Further review of the basis of the theory has found many difficulties. Vascular salt marsh plants tend to create refractory detritus. Ribelin and Collier (1979) and Haines (1979) found algal derived organic matter to constitute the bulk of marsh detritus in surrounding waters. Studies employing stable isotopic analysis have concluded that benthic microalgae produce 50 percent or more of the C assimilated by marsh consumers (Sullivan and Currin 2000). The algal consumers, such as killifish, amphipods, snails, and fiddler crabs, in turn are eaten by transient fish and bird species.

Transient marine fish may directly graze on detritus, microbes, microflora, and algae as larvae or juveniles, in the warmer, protected marsh creeks and on the marsh at high tide. By exiting the marsh in the fall, they accomplish a trophic relay to coastal waters. This may be the dominant pathway for salt marshes to support off shore fisheries (Deegan et al., 2000). Smith et al. (2000) found that mummichogs, because they may consume detritus directly and in turn are preyed upon by non-resident fish, may represent an important transfer mechanism for marsh productivity to the estuary. Transient black ducks and Canadian and snow geese feed in marshes on vegetation (Nixon, 1982) and hence export a difficult-to-quantify level of production.

The primary production that is not exported will be accumulated as peat, decomposed within the marsh, or consumed directly. Grazers consume approximately 10 percent of vascular plant production (Wiegert and Freeman, 1990). The marsh accumulates only a small portion, the majority decomposing on the marsh surface or washing away with tides. Some 60 percent of the net C fixed by *Spartina spp*. is deposited belowground as roots and rhizomes. Some is used as an energy source for new spring top growth. Most of the remainder is decomposed within the usually anoxic sediments through denitrification and sulfate reduction. After two years on a New England marsh, only five percent of the initial detritus remains (Teal, 1986). This residue resembles the resident organic marsh sediments and probably accumulates as marsh peat.

Valiela and Teal (1979) found that, because nitrogen demands exceed inputs for salt marshes, recycling of nutrients is essential, and that the nutrient exchanges between uplands and the open waters are important to structuring the salt marsh. Teal (1986) noted that nitrogen cycling in the marsh results in the conversion of nitrate to organic nitrogen (especially bound into particles) and ammonia, and that nitrogen tends to be pulsed from the marsh in the fall instead of being released more steadily with stormwater outflows. Woodwell et al. (1979) described essentially the same relationship for a Long Island marsh in the fall, but found that the marsh imported nutrients from Long Island Sound in winter. Wolaver et al. (1980) were not certain that the process was consistent from marsh to marsh, but tended to support a seasonal export model on the whole. Most denitrification (nitrate converted to nitrogen gas) in marshes occurs in the muddy bottoms of creeks (Kaplan et al., 1979), meaning that increases in creek bottomland may aid a marsh's ability to treat additional nitrate inputs.

### 5.5.2 Consumption

#### 5.5.2.1 Microorganisms and Invertebrates

Most organic matter associated with the detritus complex is derived from vascular plants. Other dead producers and consumers can contribute to detritus, but most of this is rapidly recycled, unlike resistant plant lignocelluloses. Detritus from the plant community has low nutritional value. Experimentally, no consumers have been able to grow or produce when cultured on sterile detritus (Kreeger, 1988). Decomposers, in or on plant-derived detritus, initiate the transfer of C fixed by plants to forms that can be utilized by the fauna of the marsh and estuary. Fungal activity is the key agent for detrital decay with a standing crop calculated at three (summer) to 28 percent (winter) on a per square meter basis of the living cordgrass standing crop in a Georgia marsh (Newell and Porter, 2000).

Levels of productivity for bacterial decomposers in the same marsh were about two times that of fungus in the summer and 0.07 percent in the winter. Other consumers often consume the microbially coated detritus. The bacterial biomass is digested, leaving the macerated detrital particulate substrate for defecation and subsequent recolonization, a process called "microbial stripping" (Newell, 1965). Such deposit-feeding strippers, including amphipods, gastropods, and fiddler crabs, consume the substantial fungal and bacterial biomass, resulting in high levels of secondary production.

This microbial stripping process has also been proposed for aquatic consumers such as oysters and mussels (Newell, 1965). The bacterial food they seek can be removed from the water column more efficiently when consumed with larger particles. Mummichogs have also been found to ingest detritus, but can not gain weight without the supplemental protein the microbes provide (Prinslow et al, 1974). Large young of the year (YOY) consume detritus and its microbial coating and then transport marsh surface primary production to surrounding intertidal creeks when migrating with each tidal cycle.

Filter feeders commonly found in or near salt marshes include ribbed mussels (*Geukensia demissa*), oysters (*Crassostrea virginica*), hard clams (*Mercenaria mercenaria*), and, in southern marshes, the marsh clam (*Polymedosa caroliniana*). These invertebrates are adapted to consume large quantities of seston, containing particulate organic matter from a wide variety of sources. The seston contains detritus, phytoplankton, suspended surface-associated algae, bacteria, microheterophic protests, and unidentifiable organic aggregates. As the nutritional value of these items varies greatly, they are selectively sorted and utilized (Teal, 1986; Wiegert and Freeman, 1990).

Ribbed mussels are common marsh inhabitants along the Atlantic and Gulf coats. In many cases, their biomass can exceed that of all other marsh metazoans combined (Jordan and Valiela, 1982). It has been estimated that the mussel population is capable of filtering the entire volume of water on the marsh per tidal cycle in the course of a year. Due to its dominance in both biomass and secondary production, it may be a keystone marsh species.

Despite ingesting copious quantities of suspended detritus, ribbed mussels utilize little directly. Using $C^{14}$-labeled micro-particulate detritus from *S. alterniflora*, Kreeger and Newell (2000) found it only supplies one to nine percent of the mussels' C requirements. They suspect lower rates of utilization for other bivalve suspension feeders. As with other marsh consumers, detrital consumption occurs indirectly via microheterotrophic intermediaries (detrital decomposers), with a high rate of efficiency. More than half of ribbed mussel C demands can be met through this pathway (Peterson et al., 1981; Langdon and Newell, 1990; Kreeger and Newell, 1996).

As roots and rhizomes die, their organic compounds provide energy for oxidative and fermentative transformations. The nature and rate is determined by the oxidative state of the benthic environment. Aerobic sediments are found only in the top few mm, and in microzones around *S. alterniflora* roots and fiddler crab and other infaunal burrows. Anoxic processes use nitrate and sulfate as electronic acceptors in lieu of oxygen. Both pathways yield less energy to microbes performing them than does aerobic decomposition, with sulfate reduction being less efficient. Therefore where oxygen is available, breakdown is performed by aerobic organisms. At sediment depths where no oxygen is present, denitrifying organisms dominate. Decomposition via sulfate reduction occurs deeper in the sediments and at the slowest rates. The actual amount of decomposition that flows through these various pathways is the subject of much research.

Animals feeding at the bottom of the food web in salt marshes have a wide variety of foods from which to choose. Photosynthetic organisms include the vascular plant community, epiphytic algae, macroalgae, microphytobenthos, and phytoplankton. These are mostly autochthonous with the exception of the phytoplankton imported to the marsh with flooding tides. With the great productivity of the vascular plants and high level of secondary algal production, one would expect to find a flourishing community of grazers; however, in southern marshes only two species of *Spartina* grazers are present (Wiegert and Evans, 1967).

Only a few species of marsh invertebrates consume living plant material as a sole nutritional resource, removing less than 10 percent of overall plant production (Teal, 1962). In New England marshes such as the Great Sippewissett marsh, insect herbivores include the chewers such as the longhorned grasshopper (*Conocepnaluss spartinae*) and the suckers such as plant bugs (*Miridae*), plant hoppers (*Delphacidaw* and *Cicadellidue*), aphids, and scale insects (Teal, 1986; Nixon, 1982). The only other invertebrate reported to directly feed on vascular plants were gastropod snails. They preferentially feed on epiphytic microalgae and fungi colonizing senescent plants and only consume living plant material when forced to by high population densities (Bertness et al., 2004).

Much has been made of the "detritus driven" food chain in marshes, yet as Haines (1979) points out,

> "in the purest sense, the only detritivores are the bacteria, fungi and perhaps polychaete worms which assimilate plant material directly."

Meiofaunal consumers of these organisms include protozoa and nematodes, the latter being very numerous (Kruczynski and Ruth, 1997). The feeders usually considered detritivores (fiddler crabs, snails, grass shrimp, mummichogs) actually should be classified as "opportunistic omnivores" (Haines, 1979); they defy easy classification in a classic trophic scheme. Fiddler crabs ingest algae, detritus, foraminifera, nematodes, inorganic particles, and sometimes carrion (Teal, 1962). Mummichogs are often predatory, consuming snails, grass shrimp and other crustaceans, but also filter detrital particles and algae from the water, and feed on carrion when available (Valiela et al., 1977). The marsh snail (*Littorina irrorata*) grazes on the marsh surface at low tide, ascending the cordgrass to feed on standing dead shoots and its associated microbes at high tide. Omnivory is the rule where there is a scarcity of food and variability in food type and quality from place to place or through the season (Odum, 1971). Kreeger and Newell (2000) found that no single food source could meet both the C and N demands for most consumers in a salt marsh.

Due to widespread omnivory, most marsh consumers do not fit neatly into primary and secondary consumer categories. The major fish (mummichogs), bivalve (ribbed mussel), crab (fiddler crab) and gastropod (marsh snail) species feed on both auto- and heterotrophs. Even the blue crab, a summer resident of marsh creeks, consumes submerged aquatic plants, macroalgae, and organic detritus in addition to preying upon grass shrimp, minnows, snails, and bivalves (Virstein, 1977).

By far, the most numerous "pure" predators of marsh insects are the spiders (Peterson et al., 1981). This includes web spinners such as *Grammonata spp.*, and smaller members of the family *Clubionidae*. Wolf spiders (*Lycosidae*) are also common. They hunt using visual and tactile means, even seeking large prey such as amphipods. Mites are the dominant predators of the macroarthropod community on marsh vegetation. Peterson et al. (1981) list predation and food scarcity as the major factors regulating population densities of these Arachnids.

Salt marsh sediments contain high levels of organic C, making it a desirable habitat for deposits feeding invertebrates. Meiofaunal deposit feeders include nematodes, harpacticoid copepods, amphipods, polychaetes, oligochaetes, turbellanans, and ostracods. Macroinvertebrate deposit feeders include fiddler crabs, snails, grass shrimp (*Palaemonetes spp.*), annelids, and certain bivalves (Teal, 1962).

Fiddler crabs are major consumers of marsh production and greatly impact the intertidal zone where they reside. By burrowing 10 to 30 centimeters (cm) deep, they work over much of the top layer of the low marsh each season. This increases the soil drainage and oxygen content, and in turn may enhance plant growth. Diatom-production may increase as they are brought in closer contact with light and nutrients (Montague et al., 1981). Large quantities of living and recently dead biomass are brought to the surface and deposited, hastening decomposition (Wiegert et al., 1981). Bertness (1992) called them the "earthworms of the marsh."

The marsh's dominant suspension feeder is likely to be the rubbed mussel, important for its biomass and productivity, water filtering, and deposition of nutrients in the marsh. An individual mussel may filter up to five liters of water per hour while feeding. This can decrease water turbidity, aiding phytoplankton production. The nutrient-rich feces and pseudofeces deposited can increase the growth of nearby *Spartina* by 50 percent in a season (Bertness, 1992). Byssal strands produced by the mussel serve to anchor it to the substrate and cordgrass roots, binding the marsh and decreasing erosion. The mussel shell provides a stable habitat for organisms like barnacles. Mussels have a varied diet. Phytoplankton are readily ingested and assimilated, but are only seasonally abundant. This is also the case for benthic algae that may be suspended by the tides. Detrital cellulose directly supplies little of its C needs, but associated microbes make up a large portion of a mussel's diet (Kreeger and Newell, 2000).

#### 5.5.2.2 Fish

Wiegert and Freeman (1990) noted that most fish in marine recreational fisheries require marshes for juvenile life stages. Knieb (1997) noted that most studies of marsh nekton (those creatures capable of self-propulsion horizontally) are biased towards fishes and towards species of commercial value – which tend to be transient species. Knieb (2000) also asserted that fish in salt marshes are drawn from the assemblages found in the estuary, although the marshes are said to have lower species richness. Deegan et al. (2000) called the non-resident species "marine transient" species, and identified menhaden, mullet, croaker, spot and flounder as typical examples. They also cited a report (Day et al., 1989) that found over 55 species of fish from estuaries along the eastern and Gulf coasts of the United States could be classified as marine transients. Deegan et al. do point out that it is difficult to say whether or not a fish "requires" salt marsh habitat, since it may only spend a few weeks a year in or near one. Miller and Dunn (1980) point out that transient juvenile fish may feed in estuarine environments for one of two reasons:

1. food is concentrated there due to high productivity rates; or
2. there are so few predacious native estuarine fish (often only two or three species) to compete against.

Craig and Crowder (2000) cited many studies that found estuarine fish had fuller stomachs on ebb tides as compared to flood tides, which supports the notion that they move into creeks and ditches to feed. Bertness et al. (2004) limit the use of salt marshes by fish to many commercially important species (specifying shrimp, oysters, and crab) that use the edge of the marsh as nursery areas. Nixon (1980), on the other hand, found no relationship between fisheries data and the amount of marshes near a particular estuarine system. Therefore, he thought the entire thesis of marshes serving as important nursery areas for estuarine and coastal fishes unfounded (as part of his general discussion of whether marshes serve as "outwelling" sources). Weinstein et al. (2000a) did show that bay anchovies captured several kilometers offshore from a marsh had isotopic signatures similar to salt marsh microalgae, however.

Haines (1979) noted that the true nursery area of an estuary is not the open water of the sounds and rivers, but the wetlands themselves and their creeks, because small fish forage on and use the marsh for protection. Deegan (2002) noted that it appears stem density is the true cause of predator aversion from marshes.

Several papers noted that the duration of tidal flooding (percent flooded on a monthly basis) is probably the greatest factor in determining habitat use by different species (Knieb and Wagner, 1994; Rozas, 1995; Knieb, 1997; West and Zedlar, 2000). Knieb (1984) found that *Fundulus spp.* appeared to use the marsh surface as a nursery and to reside there using puddles and pannes as habitat, although larger juvenile and adult mummichogs appear to retreat to marsh creeks in between high tides. Yozzo and Smith (1998) found grass shrimp to be the most common nekton found in tidally flooded marsh surfaces, although there were only two other common species caught, mummichogs and blue claw crabs. Some 40 percent of the captured nekton were adults, and the numbers caught correlated with the depth of inundation. They thought the data suggested seasonal shifts in habitat usage, as species that prefer submerged aquatic vegetation (SAV) may use the marsh surface for refuge as SAV dies off in autumn. On the other hand, along with mummichogs, Hettler (1989) found that spot and pinfish (*Lagodon* rhomboids) were commonly captured from the surface of North Carolina marshes. Halpin (1997) found that mummichogs preferred marsh surface habitats to more open water, and further preferred shallower environments to those with greater flooding. They are seasonal, with more fish being found in summer.

Teal and Howes (2000) suggested that the piscivorous fish found in creeks at high tides should be considered to be estuarine rather than marsh fish. Although non-resident fish are found in the marsh during summer and gut surveys of striped bass caught in marsh creeks show them to be full of mummichogs, a low level of correlation was found in a comparison of 1880s acres of marsh area and fish landings for nearby ports. This was suggestive that marshes do not support local fisheries as almost all commercial fishers in the 1880s caught fish locally. However, there was a positive correlation between the length of the marsh edge with the estuary and fish catches. Teal and Howes thus proposed that marsh edge serve as a surrogate for the amount of marsh productivity exported to the estuary. Conversely, Deegan et al. (2000) found that the warmer temperatures, shelter, and food sources found in marsh creeks made them important for larval fish of many species. West and Zedlar (2000) noted that the intermittent access to the marsh surface may mean that food resources accumulate on the marsh, and thus fish may actively seek to forage on the marsh surface in comparison to creek or open estuary areas. Rozas and LaSalle (1990) found that Gulf killifish (*F. girardis*) had fuller guts leaving the marsh surface as compared to when they entered it, which supports the hypothesis that it is an enriched food source.

At least 50 percent of the carbon used by fish and other larger organisms in the marsh comes from benthic macroalgae production (Sullivan and Currin, 2000); Pomeroy et al. (1981) found that nearly all epi-benthic algae was grazed, mostly by fish. Wiegert et al. (1981) suggested that production of primary and secondary consumers in the marsh is limited by the amounts of usable carbon generated in the marsh (algal carbon plus grazed and decomposed *Spartina* carbon). Currin et al. (2003) found evidence to support these positions, as larval mummichogs were found to consume benthic microalgae. However, adult mummichogs were shown to be at least two trophic levels removed from algae consumption, on average. This allowed them to thrive in *Phragmites*-dominated areas where algae biomass is considerably reduced. Knieb (1997) found that most research seemed to indicate that resident fish consumed detritivores, and so were secondary consumers at best.

Teal (1986) found Atlantic silverside (*Menidia menidia*), mummichog, striped killifish (*Fundulus majalis*), sheepshead minnow (*Cyprinodon variegates*), four-spined stickleback (*Apeltes quadraucus*), three-spined stickleback (*Gasterosteus aculeatus*), and American (common) eel (*Anguilla rostrata*) as the resident fish of New England low marshes, which penetrate into the grasses of the marsh when water levels would allow. Fish using the marsh as a nursery were specified as winter flounder (*Pleuronectes americanus*), tautog (*Tautoga onitis*), sea bass (*Centropristes striata*), alewife (*Alosa Pseudoharenges*), menhaden (*Brevoortia tyrannus*), bluefish (*Pomatus saltatrix*), mullet (*Mugil spp.*), sand lance (*Ammodytes americanus*), and striped bass (*Morone saxatilis*). These fish were said to be restricted to the creeks. Dreyer and Niering (1995) specified that the fish in creeks and ditches were comprised of common mummichog, striped killifish, sheepshead minnow, and Atlantic silverside, and that young-of-the-year winter flounder may be found there. Blue crab (*Callinectes sapidus*), green crab (*Carcinus maenas*), shore shrimp (*Palaemontes* spp.), and sand shrimp (*Crangon septemspinosa*) are also resident in the creeks and ditches. Other fish, especially bluefish, fluke (*Paralichthys dentatus*) and striped bass forage on these and other fish in the nearby shallow, estuarine waters. Briggs and O'Connor (1971) found 40 species of fish adjacent to island marshes in Great South Bay. The most common were Atlantic silverside, fourspine stickleback, striped killifish, mummichog, sheepshead minnow, northern puffer (*Sphoeroides maculates*), northern pipefish (*Syngnathus fuscus*), Atlantic needlefish (*Stongylura marina*), white mullet (*M. curema*), and threespine stickleback. O'Connor and Terry (1972) reported on an unpublished study at Flax Pond that found 24 species of fish, with a very different distribution. The Flax Pond study found dominance by winter flounder, and large numbers of American eels and grubbies (*Myoxocephalus aeneus*). Able et al. (2001) conducted extensive trawl surveys of five New Jersey (Delaware Bay) deep (but still intertidal) salt marsh creeks. 40 species of fish were collected (815 tows); nearly 60 percent were classified as transient species, with 40.5 percent classified as resident fish.

#### 5.5.2.3 Terrestrial Species

Large grazing mammals, common to interior grasslands, are not found in salt marshes, but smaller ones feed and find shelter here. Dense vegetation in the high marsh provides habitat for the field mouse (*Microtonus pennsylvanicus*). It feeds on *S. alterniflora* by cutting the plant at soil level while consuming only the tender basal portion. It was found to damage 2.5 percent of the *S. alterniflora* in Great Sippewissitt marsh in this manner (Teal, 1986). The seed feeding white footed mouse (*Peromysus leucopus*), as well as other small rodents, may be as common in northern marshes as the rice rat (*Oryzomys palustris*) is in the south. One of the most conspicuous marsh residents is the muskrat (*Ondatra zibethica*), whose diet consists entirely of roots and tubers. It favors low salinity marshes with low tidal variation. Larger mammals such as rabbits and white tailed deer may occasionally feed on the marsh fringes, but are not residents (Nixon, 1982).

The only reptile classified as a marsh resident in New England salt marshes is the diamondback terrapin (*Malaclemys terrapin*), which feeds on fish, mollusks, and crustaceans in marsh creeks (Teal, 1986). However, there have been reports that other turtles do use Long Island salt marshes as habitat, especially during winter (K. McAllister, Peconic BayKeeper, personal communication, 2004). Research reported later (Section 6) discusses spotted turtle (*Clemmys guttata*). It seems likely that the Eastern mud turtle (*Kinosternon subrubrum*) does not use salt marshes in Suffolk County; NYSDEC has identified mud turtles in and around the lower Carmans River, as well as the lower Peconic River and Flanders Bay areas (NYSDEC, 2003). In 1995, mud turtles were known to be in just four locations in New York, three of which were at least partially located within Suffolk County's Central Pine Barrens (CPBJPPC, 1995).

In New York, year-round populations of northern diamondback terrapins have been identified in the estuaries and tidal marshes of Long Island, Staten Island, and along the lower Hudson River into Rockland, Putnam, and Orange Counties (Feinberg and Burke, 2003). Morreale (1992) identified 993 diamondback terrapins in various estuarine environments including bays, harbors, salt marshes, and tidal creeks. 45 sites were found in the Peconic Estuary, 10 sites were found along Long Island Sound, and 18 sites were noted along Long Island's Atlantic beaches. Population densities were highest in areas containing large salt marshes with associated tidal creeks and channels. The highest densities were found in the Cedar Creek complex, the Hubbard Creek area, Scallop Pond and West Cove Creek, and the Sag Harbor complex. Morreale also noted that younger terrapins appeared to occupy slightly different habitats than older individuals.

The number of diamondback terrapins in the area has been increasing over time since the 1960s, after having plummeted during the early 20th Century due to over-harvesting (Morreale, 1992).

In 1990, the NYSDEC began requiring that persons wishing to harvest the diamondback terrapin first secure a permit to do so, although earlier reports indicate that there is generally little activity in this regard (NYSDEC and USFWS, 1998). Feinberg and Burke (2003), however, report that diamondback terrapins are still sold illegally in many major cities.

#### 5.5.2.4 Birds

Most waterfowl and shorebirds eat a great variety of plant or animal matter, or both. This may be a reflection of relative food abundance at a particular time, rather than a requirement. Mallards (*Anas platyrynchos*) capture shrimp and mummichogs to add to their diet of the macroalgae *Ruppia* and *Ulva,* which are also the mainstay of the black duck (*A. rubrides*). Canada geese may feed on *Spartina* leaves, and, in the winter, snow geese may consume large quantities of the rhizomes (Teal, 1986).

Burger (1991) stated that, generally, birds in New York salt marshes nest in different parts of the marsh: laughing gulls select *S. alterniflora*; common and Forsters terns nest in wrack-filled areas in the high marsh (as do skimmers, sometimes nesting with the terns); herring gulls nest from there up into the *Iva* layer; and herons, egrets, and ibises prefer *Phragmites* or shrubs. She did not discuss ditching as an anthropogenic problem for coastal birds in her review. Reinert and Mello (1995) generally divided habitat use between assemblages as waterfowl, gulls, and shorebirds in tidal ponds and mudflats, wading birds more abundant on the marsh than in pool habitats, and songbirds exclusively on the marsh. They further suggested that, because multiple, overlapping habitats are used by more than one assemblage, the loss of any part of the whole system could result in substantial population loss for many of the assemblages. This was asserted although the lost habitat might not constitute the primary or even secondary habitat used by any one of the bird assemblages.

Seaside and sharp-tailed sparrows (*Ammodramus spp.*) are species of concern in the northeast US due to dwindling numbers. These birds are generally considered salt marsh residents, although seaside sparrows have colonized some fresh water marshes, especially in the Hudson River valley (Post and Greenlaw, 2000). These sparrows are omnivores, with perhaps 80 percent of their diets coming from small marsh invertebrates, larger flying insects, and spiders, and the reminder from marsh grass seeds. They prefer to forage in the wetter portions of the salt marsh, although they may form loose colonies for nesting in the drier portions of the high marsh

(Austin, 1983). They catch their prey by walking on the marsh substrate, climbing through the vegetation, or wading through shallow pools and pannes (Greenlaw, 1992). It is reported that changes to marsh habitats due both to impounding and ditching have resulted in decreases in numbers; however, the heavy use of DDT in the period of 1945 to 1970 nearly eliminated most seaside sparrows from East Coast salt marshes (Austin, 1983). The distribution of seaside sparrows in south shore Long Island marshes has been described as patchy. Territories are defined in terms of reproductive behaviors, such as siting nests, caring for young, and singing. Singing requires stiff, raised clumps of plants, whereas nests need to be in or near feeding areas, have cover, and been sufficiently raised to reduce the chance of flooding. While some *Iva* or *Spartina* areas may meet both requirements, often the area used in the marsh was based on "reasonable commuting distances," in a habitat that contained all the necessary components in general proximity. This, rather than any colonial urges, is what causes the sparrows to found in loose associations. Sharp-tailed and seaside sparrows can share habitats, but the seaside is dominant when this occurs. The dominance does not affect the sharing of the overall habitat space, however (Greenlaw, 1983), although the sharp-tailed sparrow may be forced to nest in less desirable areas (Post, 1970). Breeding densities for seaside sparrows can be as high as 30 pairs per hectare (Post and Greenlaw, 1975). Seaside sparrows are unusual in north shore marshes and on the East End of Long Island (Greenlaw, 1983), and their range is from Jamaica Bay east along the south shore to Mecox Bay. They are "regularly but sparingly" sighted during mild winters, but are generally characterized as summer birds on Long Island. The population on Long Island was described as "secure" in 1992 (Greenlaw, 1992). Sharp-tailed sparrows are characterized as being common in north shore salt marshes in the summer (Greenlaw, 1983).

Very high tides drive insects and spiders out of their cover, attracting bird species like sparrow, warblers, and wrens. Kale (1965) found marsh wrens (*Cistothorus palustries*) to exert substantial control on spider and wasp populations, consuming up to five percent of the mean standing crop of spiders from April to August. Nixon (1982) lists more than 20 species of birds associated with the high marsh, attributing the high diversity to the "edge effect." This comprises the convergence of the marsh to the shore ecotone, and thus shore and wading birds are found with the field and forest species. These predacious birds may reside permanently or seasonally, attracted to fish or other aquatic species (as for osprey, kingfisher, herons, egrets, ibis, gulls) to flying insects (swallows, chimney swifts) or to small mammals (owls, harriers, hawks). O'Connor and Terry (1972) found studies enumerating at least 25 species of migratory waterfowl and 41 species of shorebirds in Long Island marshes.

### 5.5.3 Mosquitoes in the Salt Marsh Ecosystem

It should be understood that marshes are very productive sources of insects. Davis and Gray (1966) pointed out that not only are marshes sources of "noxious" insects such as mosquitoes, midges, and biting flies, but they produce a great variety and abundance of other insects, as well. Nonetheless, most ecological discussions of salt marshes do not mention mosquitoes, although extensive discussions of other insects are usually included (see, as typical, Mitsch and Gosselink, 2000, or Bertness, 1999).

#### 5.5.3.1 Adult Mosquitoes as Prey

A wide variety of dragonflies (Order Odonata) feed on adult mosquitoes that have recently emerged from swamps, bogs and marshes (Silsby, 2001), but only one species preys on salt water mosquitoes. The sole salt marsh dragonfly in the northeast US is the libellulid species, *Erythrodiplaz bernice* (Frank W. Carle, Rutgers University, personal communication). Dragonflies catch their prey on the wing using a basket-like apparatus that they form with their legs (Borrer et al., 1981). The prey of most species includes small flying insects, like midges and mosquitoes, but larger dragonflies often capture and consume bees, butterflies, and, occasionally, other dragonflies. Small insects are consumed while in flight; most species land on vegetation before they attempt to consume larger insects. Salt marsh mosquitoes often attract large numbers of dragonflies immediately after a lunar tide has produced a fresh emergence. Foraging behavior is most intense at twilight because flood water mosquitoes rest in vegetation during daylight hours, but exhibit increased activity during the dusk and dawn photoperiods. Predation by dragonflies in saltmarsh areas is more difficult to observe after the brood has dispersed. The absence of large concentrations of mosquito prey force resident dragonfly populations to shift to other food sources between the twice-monthly broods created by the lunar cycle, and/or vacate areas that previously provided excellent foraging opportunities. Most studies of dragonfly predation on mosquitoes have been with permanent swamp mosquitoes and the dragonfly species found around swamps and bogs (Kumar, 1984; Chowdhury and Rahman, 1984), and so may not be applicable to salt marsh conditions.

A variety of insectivorous birds also feed on adult mosquitoes and often take insects on the wing. Phoebes, flycatchers, and related insectivorous species feed by "hawking" (Sibley, 2001), which limits the numbers of mosquitoes in their diets. Hawking involves swooping down from a perch to glean individual insects as they are spotted, and rarely includes large numbers of insects as small as mosquitoes. The swallows and martins employ an opportunistic feeding strategy and forage far and wide for ephemeral food sources, which they take directly on the wing. When mosquito populations are numerous (*i.e.*, after a major flood water emergence), these birds are frequently seen flying back and forth over open areas taking in large numbers of aerial insects. Crepuscular mosquito behavior severely limits the time frame for energy efficient foraging with these birds. In addition, these opportunistic insect feeders must switch to a more available food source as soon as the brood has dispersed.

Purple martins (*Progne subis*) have been credited with exaggerated claims on the numbers of mosquitoes they consume. Kale (1968) provides strong arguments that refute popular claims for using purple martins for mosquito control. Almost all stomach content data show the birds eat other, larger insects; in addition, the standard foraging behavior is to fly above open fields from 50 to 200 feet above the ground; mosquitoes stay low in open country and almost never fly above tree canopies. Almost all statements concerning purple martin predation on mosquitoes prior to 1968 were either unverified reports of others' observations, or speculation based upon general behaviors. For example, the claim that martins eat 2,000 mosquitoes a day was based upon speculation by Wade (1966, cited in Kale) that a high metabolism bird such as a martin eats its own body weight in insects each day, and that the average martin weighs 4 ounces, which is the equivalent of approximately 14,000 mosquitoes. Therefore, on the assumption that a martin in an area infested by mosquitoes might feed solely on mosquitoes, the claim was based on conservatively allowing 2,000 to be consumed per day. Kale refuted each assumption, based on actual data. Therefore, it is not credible to assert the purple martin is a major predator of mosquitoes.

Bats, insectivorous mammals that include mosquitoes in their diet, are another cause for controversy regarding exaggerated potential for mosquito control. The original argument dates back to investigations using bat towers by Campbell (1907; discussed in Murphy [1989]), Storer (1926), and Allen (1939). In all cases, the hypotheses appeared sound, but failed to produce the desired results. Numerous claims regarding the numbers of mosquitoes that one bat can eat in an hour routinely appear in popular articles and web sites (e.g., McAvoy, 2004). Claims vary from 300 to 600 per hour, and are usually then re-calculated to reveal the number of mosquitoes each bat consumes every night, often from restricted areas (such as one backyard). Most figures are based on sonar studies where bats were purposely released in a room filled with mosquitoes to compare the efficiency of sonar-directed foraging versus random catch. The stomachs of these experimental animals provide the data cited by bat enthusiasts on the numbers of mosquitoes consumed by bats per hour. Corrigan (1997), following Masters Thesis work on the subject, has written a number of non-technical articles on the feeding behavior of bats as well as the mosquito-bat controversy. His research indicates that the little brown bat (*Myotis lucifragus*) prefers small, soft-bodied insects and does include mosquitoes in its diet. Larger bats such as the big brown bat (*Eptesicus fuscus*) are more opportunistic and prefer beetles and moths because of their size. Bat feeding strategies, however, are to consume as much food as they can in the first hour and either rest or return to the roost. Most of the figures for bat predation are based on the mistaken assumption that bats continue peak feeding efficiencies throughout the night. Corrigan's research also indicated that bats often tend to feed in areas where electric lights attract large numbers of insects. As a result, they frequently feed selectively on moths and beetles at a single focal point rather than combing a wide area, or away from lights where mosquitoes are more likely to be.

Various stomach content or feces examinations also show mosquitoes are not important food sources for bats. Eastern red bats and evening bats feces composition were compared to UV trap contents in South Carolina, and it was found that Diptera (the order containing mosquitoes) were underrepresented in the feces compared to trap contents (Carter et al., 2004).

On the other hand, it was noted that the *Myotis* genera of bats will consume flies and smaller moths. However, sporadically available foods (the examples cited were caddisflies, mayflies, termites and ants), since they are unavailable most of the time, cannot be specialized on. Nonetheless, when available, they may be preyed on enthusiastically. This suggests it is difficult to collect reliable information on bat feeding habits, especially for ephemeral prey such as mosquitoes (Whitaker, 1994). Although bats that "glean" (use echolocation for specific insects) tend to eat only large insects such as beetles and moths, other bats will forage on smaller insects if they are swarming (most bats stomach or feces contents consist of one to four "kinds" of insects) (Whitaker, 1988). Studies have found that certain bats will feed extensively on Nematocera, the suborder including mosquitoes (Swift et al., 1985), and Whitaker included mosquito parts in his key to identifying bat meals (Whitaker, 1988). Kunz (1988) determined that mosquitoes are a relatively nutritious meal for bats, having an average energy equivalent per mass unit compared to other insects, suggesting they will be sought if numerous enough. This suggests that bats may prey on salt marsh mosquitoes in the salt marsh, when they are relatively concentrated, but are unlikely to preferentially seek mosquitoes after they disperse. This is especially true because bats seem to focus on areas where insects are most numerous (identified in one paper as areas with riparian vegetation, over water and watercourses, and around trees [Racey and Swift, 1985]).

#### 5.5.3.2 Mosquito Larvae as Prey

A wide variety of predacious insects feed on mosquito larvae during their aquatic developmental stages in fresh water environments. However, flood water mosquito species, in general, live in transient water habitats and undergo rapid development which significantly reduces opportunities for insect predators to utilize them as a food source. Salt marsh flood water supports even fewer insect predators because of the limiting factors that high salinity poses.

Predacious fish are probably the most efficient predators of mosquito larvae and have the ability to completely control mosquito larvae if managed properly (Gerberich, 1985, Haas and Pal, 1984). Salt marsh mosquito producing habitats in the northeastern United States have large populations of mummichogs, which can be managed to function as a voracious predator of *Ochlerotatus sollicitans* and other salt marsh mosquito species. Salt marsh mosquitoes generally lay their eggs on areas of high marsh dominated by *S. patens*, which can grow so closely that it tends to screen mummichogs from the larvae that develop in depressions on the high marsh. The fish can gain access to breeding depressions during lunar floodings by swimming over the grasses, but become stranded and die when the tide subsides and the pools dry down. This allows the eggs to develop into larvae during the next flooding period if the fish cannot reach the pools again.

However, fish that prey on mosquito larvae are not dependent on mosquitoes for sustenance. A study in Mississippi examined gut contents of killifish before and after the fish went onto the marsh surface. Rozas and LaSalle (1990) did not find enough mosquito larvae in the fish for larvae to make the list of primary prey. Fiddler crabs and amphipods were the dominant prey, along with tanaidaceans and hydrobiids (polychaetes).

However, under circumstances where mosquito larvae are extremely abundant, certain marsh surface fish were found to feed exclusively on mosquito larvae. A high marsh in Florida was flooded at the time that a brood of mosquitoes was almost ready to hatch, providing general access for fish to the breeding points. Harrington and Harrington (1961) found that mosquito larvae can constitute between 50 and 90 percent of some species' diets when abundant. The fishes revert to other, various food sources that include vegetative matter and detritus, copepods, other fish, or other insects and insect larvae, depending on the species, when mosquitoes are not available. Because mosquitoes tended not to be abundant most of the time in this marsh, insects, in general, constituted only two percent of the fish prey by mass for the overall study, in which a total of 16 fish species were sampled.

### 5.6 Important Suffolk County Salt Marsh Mosquitoes

Mosquitoes that breed in salt marshes are dessication-tolerant species. This means that the eggs must dry down for a period of time for development to larvae to occur when they next become wetted. Marsh mosquitoes therefore lay eggs on moist ground following a flood event (the presence of moisture indicates that the ground should flood once again). The eggs then wait for the next flooding event. For salt marsh mosquitoes, this will be a higher tide (as if the eggs are laid in the zone that is flooded daily, they will not have enough time to dry down to allow for development). Thus, the high marsh (by definition, the part of the marsh that is not regularly flooded by tides) is the part of the marsh that supports breeding) (CA-CE, 2004).

Development following flooding by the tide is dependent on the larvae finding habitat that will last long enough for it to complete development. Therefore, it is not enough to wet the egg with a tide or rain storm; the egg and then the developing larvae needs an aquatic habitat until it finishes pupation. The amount of time this requires is controlled by temperature; therefore, earlier in a season the water supporting breeding must be more persistent than later in the summer. Therefore, more of a particular marsh can successfully breed under the same flooding conditions compared to earlier in a season (CA-CE, 2004).

Development times can be less than a week in warmest weather. Males develop a little more quickly than females. After females metamorphose, they have a single mating over the salt marsh, and then begin to search for blood meals to provide proteins to support egg development (feeding on nectar from flowers and other plants supports basic metabolic functions). The females migrate to the edge of the marsh (assuming they do not encounter a food source on the marsh first), and then migrate out off the marsh. Therefore, the impacts of a brood of salt marsh mosquitoes will be greatest no less than one week after the tide or storm that initiated development, and, if the weather has been cooler, the impacts on neighboring residents may first be felt as long as two weeks after the high tide (CA-CE, 2004).

After a blood meal, the female mosquito will return to the marsh, lay her eggs, and then search for more blood meals. Laying eggs leaves scars on the mosquito ovary, and so the number of times a mosquito has oviposited can be determined (a nulliparous mosquito has not laid eggs, a parous mosquito has). Determining parity is a means of assessing risks for mosquito-borne disease, as most diseases of concern are transmitted horizontally – through a host organism, rather than vertically (from mother to daughter). Parous mosquitoes clearly have had a blood meal, which means they may have become infected with a pathogen (Cashin Associates, 2005c). Hosts for the diseases of concern in Suffolk County are other people for malaria (and since malaria is not common here, this disease is not of great concern) and birds for WNV and EEE. Therefore, a mosquito that transmits the arboviruses of greatest concern at this time need to be somewhat indiscriminant in its feeding selections, as not only must it cross species lines, but also change its preference from avian blood to human blood (Cashin Associates, 2005b). Salt marsh mosquitoes will thus be of greatest concern if they were to encounter habitat where a disease amplifies in birds, and then find a residential area. For EEE, where virus amplification only occurs in specific habitats, the transmission risks for disease are somewhat more predictable. In New Jersey, it is clear that the confluence of Atlantic white cedar swamps (where the virus amplifies) with salt marshes (where the mosquito with greatest potential to spread the disease, *Ochlerotatus sollicitans*, breeds) provides the greatest degree of risk to people (Cashin Associates, 2005d). WNV dynamics, especially for salt marsh mosquitoes, are not as well defined. For one, salt marsh mosquito species are generally not thought to be the best transmitters of WNV from birds to people, although almost all are deemed to be capable of doing so (Turrell et al., 2005). However, WNV amplification is also not limited to discrete habitats, but is generally thought to occur especially well in residential settings (the house mosquito feeding on the house sparrow, for example) (Cashin Associates, 2005b). Therefore, salt marsh mosquitoes found in residential settings may have encountered infected birds (either in an interrupted meal or a previous foray into the community) and so constitute a threat of disease transmission.

There are few developmental differences between the various species of salt marsh mosquitoes. Some develop better under cooler conditions (and so are more prevalent earlier in the season) and some are not as tolerant of salt conditions (and so develop in brackish or upland edges of the marsh). The species of interest, with some salient features, are listed in Table 5-3.

Table 5-3. Major salt marsh mosquitoes of Suffolk County

| **Species** | **Notes** |
|---|---|
| *Aedes vexans* | Predominantly fresh water, but tolerates brackish breeding sites |
| *Culex salinarius* | Predominantly fresh water, may breed in brackish areas of salt marshes more later in the season |
| *Ochlerotatus cantator* | Early emergent |
| *Ochlerotatus sollicitans* | Fierce, persistent biting mosquito that is very prolific |
| *Ochlerotatus taeniorhynchus* | Fierce and persistent mosquito, not quite as prolific as *Oc. sollicitans* |

## 5.7 Background Information on Open Marsh Water Management (OMWM) (Progressive Water Management)

### 5.7.1 Introduction

Progressive water management is often called OMWM. OMWM is typically one of three implementations:

- open systems
- semi-open systems
- closed systems.

The classes are determined by the degree of connection to the estuary. An open system consists of tidal channels connected to relatively deep tidal outlets which, when combined with spur ditches, permit daily tidal exchange. A semi-open system consists of “full-depth” (approximately one meter) channels with a shallow tidal outlet or sill combined with lateral spurs, creating a system with some, but not complete, tidal exchange for each tidal cycle. Closed systems contain shallow pools, deeper reservoirs, and pond radial ditches with no associated tidal outlet (Dale and Hulsman, 1990). Tidal exchange in a closed system occurs only during spring or storm tides. Very often the existing mosquito ditch network is used or modified to create the OMWM channels, and so the word "ditch" is often used interchangeably or synonymously with "channel" in describing OMWM systems.

Alternatives to grid ditching were identified soon after the introduction of the technique, and were called "quality ditching." Biologists realized that mosquitoes only bred in relatively restricted areas of the marsh. Quality ditching addressed only the high marsh, and was designed to increase killifish access to breeding areas while also draining some of the standing water found there where mosquitoes bred (Smith, 1904). The primary breeding area for mosquitoes in salt marshes is the intermittently flooded high marsh. Uneven terrain can cause portions of the marsh surface to retain tidal floods for longer periods of time. These small areas, called potholes, commonly range in size from several inches to several hundred feet in diameter, and range in depth from several inches to up to a foot. They must dry out at least partially to be a site for mosquito breeding. The female salt marsh mosquito lays her eggs (100 to 200, typically) on moist mud. The egg must remain dry for several days. Once the eggs are completely inundated after drying down, they will start to develop. Adults emerge in less than a week (or as long as 14 days, depending on temperatures), and for that entire time the larvae must remain in water. Therefore, a breeding site will not be found where daily tides reach, nor can areas subject to drainage or rapid evaporation support breeding. Larval mosquitoes will dive to the bottom to avoid predators, but otherwise they are relatively defenseless, especially against fish. Therefore, breeding is most successful in isolated, shallow, shaded depressions in the high marsh. These can commonly develop around the root clusters of *Spartina patens*, as the roots trap sediments better than surrounding bare soils, and so elevate themselves above the base plain of the marsh, causing the phenomenon known as "ankle-busters" or potholes (Lesser, undated).

In 1966, in Cumberland, New Jersey, Edward Smith and Patrick Slavin developed a mechanized means of controlling breeding, and one that minimized impacts on non-breeding areas of the marsh. The technique was called Open Marsh Water Management, as it involved active management of the hydrology (i.e., water management) of the uncanopied salt marsh (i.e., the open marsh). It involved the construction of channels to augment tidal flows to ensure the circulation of good quality estuarine water into the high marsh area. There, where breeding was found, ponds were excavated at the most intense breeding sites, and the sediments were spread in a thin slurry out into auxillary mosquito habitat where potholes promoted additional breeding. Linear radial ditches were also dug to areas of concentrated breeding. Typical pond depths were six to 12 inches (for optimal water fowl usage), with deeper sumps installed to allow for fish protection from wading bird predation. Killifish benefited most from this technique, and flourished as long as proper water quality reached the ponds (and adequate refuge was achieved through deepened sections of the ponds). The killifish foraged across flooded sections of the marsh, and whether by consumption of eggs, or predation on larvae, prevented successful mosquito breeding from occurring (along with loss of habitat through the spread of the pond spoils). Thus, through habitat deprivation and predation, mosquito breeding was controlled, while the pond and tidal creek portions of the marsh food web were enhanced (Ferrigno et al., 1975).

After carefully defining the scope of water management practices as the area where mosquitoes actually breed (not the whole marsh, or even all of the high marsh), Shisler (1978) enunciated the three basic principles of habitat manipulation to prevent mosquito emergence:

- Remove excess surface water

  The intent here is to disrupt the short period (as little as five days) that salt marsh mosquitoes require to mature from egg to adult. Ditch placement to drain breeding areas, and spoil placement to fill potholes are the methods to achieve this.

- Increase the amount of standing water

  Salt marsh mosquito eggs require dry down prior to maturation. Permanent water (or supplying water during breeding seasons) prevents this from occurring.

- Increase the movement of water

  Mosquitoes need slow-moving or stagnant water to break through the surface film to air-breathe, while remaining in a relatively fixed location.

New Jersey thus fashioned its OMWM strategy based on the pond, radial ditches from the pond, and tidal ditches. The pond serves as the permanent standing water, and so is placed in the most concentrated area of breeding. The pond also serves as habitat and refuge for killifish, which serve as the biological portion of the control strategy, consuming larvae where they can be accessed. The radial ditches from the pond can drain standing water off the marsh, preventing excess surface water from collecting. They are thus installed towards other areas of breeding. Radial ditches also allow for killifish access from the pond refuge into the high marsh. The tidal channel increases flow through the system, ensuring any permanent water does not become mosquito habitat, and increasing water quality to support killifish survival. All of these elements also have ancillary wildlife benefits. Tidal ditches serve as good habitat and foraging areas for estuarine fish. Tidal ditch connection to many ponds addressed fishery concerns that constructed ponds would become isolated and stagnant, and so lose habitat values. The ponds serve as important shore bird habitat, as do radial ditches where water levels fluctuate with the tides (thus exposing sediments to foraging). Shisler also noted the development of stop ditches, where ponds were created by simply plugging an existing grid ditch. These stop ditch systems, which maintain higher water levels than tidally connected systems, and any isolated ponds, can be flushed during higher lunar tides. This will not only restore water quality, but provide “product” to the estuary in terms of biomass of algae, vegetation, and fish.

### 5.7.2 Practices in the Mid-Atlantic and New England States Other Than New York

#### 5.7.2.1 Maryland

OMWM was undertaken in Maryland in the late 1970s, where it was described as the primary means of mosquito control (Lesser et al., 1978). A study of its impacts found vegetation changes in the high marsh areas, with the closed system supporting more salt tolerant plants, and the open and semi-closed systems supporting some upper marsh plants. Differences in vegetation and nutrient concentrations (in plants) were found across each site, especially closer to the OMWM waterways. No difference water quality was noted compared to control sites, and fish were well established at all areas with permanent standing water (Whigham et al., 1982). However, Maryland has moved away from OMWM as a marsh management tool. Partially this is due to concerns regarding the potential to increase salinity in fresh water or brackish marshes with more vigorous tidal circulation, and also partially it is due to the specific local problem of excess subsidence leading to marsh drowning – so that any extra in-marsh water is something to be avoided. Some managers have even supported planting *Phragmites* as a stopgap measure, due to the ability of *Phragmites* to capture sediments more efficiently than most other marsh plants and so raise the surface of the marsh above encroaching water. The maintenance of marsh habitat type was deemed to be a greater good than the loss of marsh quality by replacing other high marsh plants with *Phragmites* (partially because the Maryland studies found fewer habitat changes associated with invasive *Phragmites* than others have found) (Stevenson et al., 2000).

#### 5.7.2.2 Delaware

Delaware enthusiastically supports OMWM; its programs were initiated in 1979. The first decade of work there saw treatment of approximately 4,000 of the 15,000 acres of mosquito-breeding marsh in the state, and a concommitant decrease of 25 percent of the area of marsh needed to be treated with larvicides (Wolfe, 1992). It is used to further two mosquito control-associated goals, and one general marsh management end. Delaware seeks to reduce mosquito breeding and yet also reduce its use of insecticides. It also seeks to enhance habitat for salt marsh fish and other marsh wildlife. Factors that influence design choices include where mosquito breeding occurs, and predicted long-term water quality in any created water bodies. This is because good water quality ensures fish survival, and healthy killifish lead to mosquito control. Delaware has found that limiting the use of open tidal systems reduces the potential for vegetation and water level changes within the marsh, and that pond systems enhance habitat for shorebirds, water fowl, and marsh mammals (Lesser, undated).

OMWM practices used on Delaware marshes include open tidal systems with restricted tidal exchange, and closed nontidal systems. The type of OMWM technique used is largely based on the type of mosquito breeding being addressed and concerns regarding long-term water quality within OMWM ponds and ditches. The most common OMWM technique implemented in Delaware includes infrequently flooded or semi-tidal permanent bodies of water in high marsh vegetation (Lesser, undated). Open tidal ditches are used in a very limited capacity due to the undesirable effects on hydrology and vegetation that may result from excessive drainage. Mosquito breeding areas found in large shallow pannes are treated with a sill outlet to allow the surface sheetwater to drain during ebb tides, while still maintaining groundwater levels. Excavated spoil material is deposited on-site to fill adjacent mosquito breeding potholes, or is thinly spread across the marsh surface so as to not impact existing vegetation (Wolfe, 1996).

By 1994, approximately 1,260 of 1,350 potential breeding areas at Prime Hook National Wildlife Refuge had been treated with OMWM. A total of 234 ponds were created, providing over 19 acres of open water habitat, with the intent of reducing or potentially eliminating the use of insecticides for the next 20 years (Wolfe, 1996).

In 2001, the USFWS initiated a three-year study of OMWM throughout Region 5, the northeast US. The study was intended to use a rigorous BACI (Before-After, Control-Impact) study design to determine the ecological impacts of ditch plugging, which was the predominant form of OMWM for the sites selected. The study was somewhat impacted because almost all of the selected sites had, in fact, been plugged prior to the study start. However, it is still a comprehensive, multi-site, multi-parameter assessment of the effects of ditch-plugging, one that uses control sites and multiple years of data collection to offset some of the variability among individual marshes. In Delaware, the study was set in Prime Hook National Wildlife Refuge, using sites in Petersfield (6.5 hectares, originally sill ditched in 1989, but now extended to full ditch plugs in 2002) and Slaughter (a 6.5 hectare site, with ditch plugs installed in 1992 – those that failed were replaced by sill ditches in 2002) (James-Pirri et al., 2001; James-Pirri et al., 2002).

#### 5.7.2.3 New Jersey

OMWM is the major source reduction technique used by coastal mosquito control agencies in New Jersey. OMWM techniques were initially developed in New Jersey through the cooperative efforts of the coastal County Mosquito Commissions, the New Jersey Division of Fish, Game and Wildlife, and Rutgers University (Ferrigno and Jobbins, 1968). In 1980, New Jersey published *Standards for Open Marsh Water Management*, which was adopted by both state and Federal regulatory agencies for use when evaluating applications for water management projects on salt marshes (NJDEP, 1980).

According to Ferrigno and Jobbins (1968), in the seminal description of Open Marsh Water Management, in order to obtain complete mosquito control for longer periods of time, every breeding and potential breeding depression on the marsh has to be identified prior to implementing any OMWM techniques. Each depression must be connected to a tidal ditch to allow tidal circulation, or to some other kind of permanent body of water, to insure access for fish that consume mosquito larvae. Deeper ditches were recommended because they are more efficient at transmitting water; therefore, they provide better circulation and greater degrees of tidal inundation, and tend to be more persistent marsh features. If any permanent water areas were apparent, such as ponds, it was recommended that they should be preserved and isolated from the rest of the ditching system to ensure they maintained water levels and served as effective fish reservoirs.

In order to achieve an effective OMWM system, Ferrigno and Jobbins (1968) advised adherence to the following precautions:

- Quality ditches should be constructed at least two feet deep in order to have water flows reach low marsh areas. Deeper ditches (more than three feet deep) are preferred when reaching high marsh areas.
- Mains should be connected on both ends to tidal ditches or band ditches. Band ditches are recommended along the upland edges with spoil placed on the upland side at irregular intervals.
- Lateral ditches should be straight and connected at both ends, to prevent silt deposition.
- Ditches with a gradual decrease in elevation will lead to revegetation of the ditch bottom, leading to re-isolation of breeding depressions, and so lead to renewed mosquito breeding.
- Spoil should be graded with the marsh surface to provide the least interference of water moving over the surface of the marsh.

Three basic OMWM types used in New Jersey involve the construction of tidal ditches, ponds, and pond radials, also called spurs. These techniques are confined to high marsh areas vegetated by *S. patens* and *S. alterniflora*. Since 1970, several thousand hectares of salt marsh have been treated with OMWM techniques and larvicide applications have been eliminated (Barnegat Bay National Estuary Program, 2001).

Egg Island Fish and Wildlife Management Area located in Cumberland County was chosen to determine the effects of OMWM on mosquitoes in the late 1960s. The marsh vegetation was primarily *S. patens* and was riddled with thousands of depressions created by large populations of wintering snow geese. Following a three-year, post-OMWM monitoring period, it was estimated that for every 1,000 acres altered, 40 to 60 billion mosquitoes would be eliminated annually without the use of larvicides for as long as the ditching remained effective (Ferrigno 1970).

The Bombay Hook Wildlife Refuge marsh project had a signature design of "natural" pools. These are not intended to entirely drain the surrounding area and generally have irregular shorelines. The OMWM also included the construction of "blind sumps," which are deepened potholes with radiating ditches dug to low portions of the surrounding area to facilitate drainage, and "champagne pools," which are similar to blind sumps, but with a controlled outlet to the estuary. Bodola (1969) studied the effectiveness of these ponds on mosquito control and reported that all of the pools studied were effective in reducing the number of mosquitoes produced.

CA personnel visited OMWM sites in Ocean County in May, 2004 and May, 2005. Ocean County has approximately 27,000 acres of tidal wetlands, much of which are managed by USFWS. Ocean County Mosquito Control believes most of its breeding problems come from the inundation of high marsh, where water is not completely transported away at the end of the tidal cycle. This could be due to hummocky terrain, clogged ditches, berms, and tidal restrictions. When a trouble spot is identified, a standardized approach is used to address it via OMWM.

Stakes are arranged in various ways at the site by supervisory personnel to indicate pond areas, spoils deposition areas, and ditch cleaning/construction areas. The operator of the machine, typically a rotary ditcher, has a great deal of latitude in following these broader guidelines. It may be that too much material is produced from pond construction to follow the spoils plan, or that the construction of the pond requires alteration due to on-the-ground conditions. The experience of the operator and the continuity of supervision allow the operator to meet the intent of the plan without following instructions exactly. The general plan of action is to excavate ponds in the densest areas of mosquito breeding, fill in hummocky areas with spoils, and, through ditch construction and maintenance, ensure there is tidal flow to the region following the work. Ponds tend not to be connected directly to the ditches. Ponds tend to be small, generally, room sized rather than substantial portions of acres. The ponds are sinuous, multiple-pass ditches that close back in on themselves, creating and island or islands. A lip is created along the outer edge of the pond, and otherwise depths are on the order of three feet.

Figure 5-2. New Jersey marsh after OMWM

OMWM sites that were five or more years old had natural-appearing features, supported fish, and seemed to have persistent features that needed no maintenance. The sites tended to revegetate with the surrounding vegetative community, although there were some transitions from high marsh to low marsh in areas where tidal circulation was increased. The use of spoils to fill the hummocky areas meant that many sites, even those three years old, had very extensive bare spots. The degree of barrenness is a function of whether the site supported vegetation prior to the work, and the depth of the spoils placement. Improvements in tidal circulation, together with aggressive mowing in places, appeared to keep *Phragmites* in check, and sometimes to cause retreats.

Project success is measured in terms of larvicide application reductions. Each mosquito season, Ocean County maps the number of times each marsh tract is larvicided. Areas that have had OMWM installations show large reductions in applications each year, although total elimination of larvicide use is generally not achieved.

#### 5.7.2.4 Connecticut

In 1985, Connecticut determined that its practice of ditch maintenance should be gradually replaced by OMWM installations. This was adopted, not only as a mosquito control practice, but as part of an overall salt marsh restoration program. In fact, many Connecticut OMWMs are installed primarily for wetlands reclamation or restoration purposes, rather than as mosquito source control. Connecticut now refers to its efforts in tidal wetlands as Integrated Marsh Management. It is comprised of four major, interwoven components:

- mosquito management (mostly, OMWM replacing ditches)
- marsh restoration (tidal connection improvement and marsh re-creation)
- vegetation management (predominantly, *Phragmites* control)
- public education

(Wolfe et al., undated)

Connecticut has a rigorous site approval process, albeit one where the structure and content of the site review has been optimized over 15 years of experience. Although largely internal to the Connecticut Department of Environmental Protection, other involved stakeholders including those from interested Federal parties (e.g., USFWS and Army Corps of Engineers) are involved. Designers attempt to reconcile potential conflicts between technical experts; common sources of disagreement are the views of bird and marsh vegetation natural resource specialists, as gains in bird habitat often occur at the expense of wetlands plant acreage. Following a preliminary design of a project, at least one extensive site visit is made by all of the participants in the review process. The design is then altered, using consensus as the means to ensure optimization (P. Capotosto, CDEP, personal communication, 2004).

Sites where OMWM has been implemented do not require larviciding, and maintenance of the installed structures has not been necessary. Connecticut's preferred OMWM technique is the use of full ditch plugs coupled with constructed open water areas. Sill ditches may be used to connect ponded areas to breeding sites. Improvements in water fowl habitat have been the most notable environmental impact, although, as part of the Integrated Marsh Management program, Connecticut does not like to single out particular aspects as having primacy over others (Wolfe et al., undated). Paul Capotosto (CDEP, personal communication, 2003) notes that none of the projects completed since 1985 have required maintenance to date. Also, none of the OMWM sites requires regular larviciding, and, except for instances associated with unusual environmental conditions such as exceptional rains or tides, none of the sites requires any larvicide applications.

Figure 5-3. Aerial view of an OMWM marsh in Connecticut

#### 5.7.2.5 Rhode Island

The salt marshes in Rhode Island are not as extensive as New Jersey or Delaware marshes, ranging from two to 150 acres in size. As early as 1937, it was recognized that standard ditching should be modified as the primary means of mosquito reduction. A new focus was initiated to bring more water onto the entire marsh surface instead of draining the marshes through ditches (Price, 1938).

All ponds and potholes throughout the marshes on Prudence Island were connected by shallow, 15 to 18 inch-wide ditches in 1937. One main outlet was cut in each area to Narragansett Bay. Each tide completely flushed all the ponds and potholes, and delivered a new supply of Killifish. These ponds and potholes were free of mosquito larvae within a year after the alterations to the marsh; this was not the case in a marsh where no quality ditching had been applied. Additionally, the water table appeared to be restored to its pre-ditching levels, and ponds that formerly were stagnant and dried out were supplied with water on every tide (Price, 1938).

Christie (1990) generated a manual for Rhode Island marshes, based on experience at one site in-state, the Seapowet Management Area, Tiverton, and the 1986 Massachusetts-Audubon manual. The manual called for ditch plugging with pond creation. This succinct manual addressed salt marsh geology and ecology, mosquito ecology, and OMWM theory, preparation, permitting, construction, and monitoring in 30 pages (including appendices). It included an OMWM justification model attributed to Sjogren and Genereux (1987). This is a formulation of an OMWM index:

$$I = MA \times SC \times AC$$

where

MA = percent of the marsh generally capable of breeding mosquitoes
SC = number of field visits where dip counts exceeded five per dip (sufficient count)
AC = average mosquitoes per dip in the sufficient counts

If the index (I) exceeded 100, an OMWM may be justified.

The Rhode Island manual supported the use of full ditch plugs (closed systems), with an edging ditch installed to minimize fresh water intrusion. Ponds tended to be large, up to 100,000 square feet, which is more than two acres (Christie, 1990).

As an example of the kind of project undertaken in Rhode Island, a small salt marsh on Block Island (named Mosquito Beach, apparently for its profusion of mosquitoes) was addressed in 1997. A channel blockage was cleared, two small ponds installed, and ditches cleared to enhance access to breeding areas in the marsh. One unneeded grid ditch was filled. The project was reported to have met its mosquito control goals almost immediately, and appeared to have enhanced the marsh's ecological values (mostly through restoration of tidal circulation) (James-Pirri, 1998).

#### 5.7.2.6 Massachusetts

In Massachusetts, OMWM design selection depends on the specific physical and biological characteristics of the marsh. The main characteristic in determining the need for OMWM alterations is the number of mosquito larvae present on the marsh during the breeding season (Hruby and Montgomery, 1985).

For example, in Essex County, OMWM is implemented only if at least three broods are observed during the summer, and the average larvae dip count is greater than five. If two broods are observed with this high average number, another season of monitoring takes place before a final decision is made. Before a marsh in Essex County is considered for OMWM, additional information regarding the level of spring tides in breeding areas, as well as the distribution of the existing vegetative communities on the marsh and upland edge are well documented. A qualitative understanding of fresh and salt water flow patterns, levels of dissolved oxygen in existing ditches and pools, and salinity and temperature measurements in major bodies of water are also components of pre-monitoring efforts (Hruby and Montgomery, 1985).

OMWM reservoirs on Massachusetts marshes must be constructed to a depth of three feet and a width of two feet. Vertical sides for reservoirs are preferred in order to eliminate shorebird predation. Reservoirs are placed within 55 yards of breeding areas and are at least 100 square feet in surface area. Preferably, reservoirs are constructed from existing tidal pools, existing perimeter ditches, or existing ditches. If none of these exist, new reservoirs are dug at the edge of shallow permanent or temporary pools, or existing depressions (Hruby and Montgomery, 1985).

Spurs are constructed 18 inches deep and 18 inches wide and extend from the middle of a reservoir to an edge of a breeding area. Shallower spurs are not recommended. A 95 percent reduction in larval numbers was achieved when spurs were within 75 feet of each other in large mosquito breeding areas (Hruby and Montgomery, 1985).

The Massachusetts OMWM manual ((Hruby and Montgomery, 1985) further recommends that ditch plugs be constructed from dredged spoil to a length of at least 50 feet long, and should be four inches to six inches above the marsh surface (due to eventual subsidence of the emplaced material). In areas where muskrats are active, plugs are constructed 100 feet long to prevent the animals from burrowing through the plug to the tidal channel. Excavated spoil from digging or cleaning operations are not set on the marsh surface if it will raise the surface above the level flooded by spring tides. No more than three inches of spoil on the marsh surface is permitted during the disposal of spoil.

Marshes in Massachusetts that breed mosquitoes are rather small in scale and, therefore, are not best suited for the construction of large OMWM ponds. Instead, small reservoirs are created by digging ditches that are approximately three feet deep, and 18 inches wide. During the reservoir construction, old ditches that are open to tidal flow are cleaned out and remain open. This allows the sediments in the ditch to settle, and allows the ditch to become oxygenated. After a month, the seaward end of the ditch is plugged to the level of the marsh surface with a spoil plug. Old upland perimeter ditches are preferred for reservoirs due to their proximity to major mosquito breeding areas. Radial ditches are constructed, 18 inches deep by one foot wide, to connect mosquito breeding sites to the reservoir. The radial ditches are not connected to the tidal channels, reducing the potential to drain the water table (Hruby et al., 1985).

Three salt marshes on Nantucket were treated with water management techniques in the winter of 1992/1993 for mosquito control. These marsh sites consisted of Eel Point, Warrens Landing, and Madaket Ditch. Eel Point was treated with OMWM techniques that involved the transformation of an overgrown ditch into a reservoir and a radial ditch, combined with the backfilling of the remainder of the ditch with spoil. Existing mosquito ditches were re-opened at Warren's Landing and a spoil ridge blocking the marsh from tidal channels was cut. At the Madaket Ditch marsh, existing ditches were re-opened to channel fresh water through the salt marsh, an OMWM system was created throughout the marsh, and a spoil ridge from original ditching was cut. All three installations appeared to be successful, as mosquito breeding was virtually eliminated within one year (Christie, 1993).

Parker River National Wildlife Refuge had a 3.5 hectare area plugged and radially-ditched in 1994. An additional two sites, comprising 16 hectares in total, were similarly treated in 2002, as part of the USFWS Region 5 study of OMWM impacts (James-Pirri et al., 2001; James-Pirri et al., 2002).

#### 5.7.2.7 Maine

Hundreds of restoration projects have been completed in the Gulf of Maine. However, historically, sufficient information has not been compiled to adequately track these projects (Cornelisen, 1998). Long-term evaluation of the state's restoration projects is inhibited due to the absence of baseline data and inconsistencies in data collection.

A study at Rachel Carson National Wildlife Refuge evaluated the response of three salt marshes, Granite Point Marsh, Moody Marsh, and Marshall Point Marsh, to the practice of ditch plugging. The study focused on the effects of ditch plugging on marsh hydrology, sedimentation and marsh development processes, vegetation patterns, and utilization by nekton and birds. As a result of the ditch plugging, water table levels and standing water increased. Vegetation observed in this study shifted from *S. patens* to *S. alterniflora* at Granite Point and Marshall Point. No significant vegetation change was noted at Moody Marsh. Nekton species richness, total fish density, total decapod density, and nekton community structure were unaltered following ditch plugging at both Moody and Granite Point marshes. When compared to the associated control marshes, nekton richness and density were greater at Marshall Point, and total fish abundance and bird species richness were greater at Granite Point (Adamowicz and Roman, 2002).

#### 5.7.2.8 Region 5, USFWS

USFWS is a large landholder in east coast salt marshes. USFWS would also like to eliminate pesticide use in its Refuges, but also maintain its policy of being a good neighbor to surrounding communities. Its perception is that this role includes preventing, as much as possible, mosquito problems to exist due to breeding on the Refuges. OMWM holds a promise of meeting these two goals, and, potentially, of providing collateral wildlife values enhancements.

Initial guidance had been offered that closed (ditch plug) systems and semi-open (sill systems) were preferable over open systems. The exception was the use of open systems to address *Phragmites* invasion. USFWS appeared concerned that open systems would serve to drain the water table excessively (Taylor, 1998). However, noting the lack of standardized information on OMWM benefits and potential impacts, the advisory was slightly altered in 1999 that determinations regarding OMWM projects be made at the specific Refuge level (USFWS, 1999), pending the outcome of initial (Roman, 1998) and long-term (James-Pirri et al., 2001) projects. The initial evaluation, in Maine for ditch plugging, found shifts in vegetation toward *S. alterniflora* due to increased water levels, Bird responses were variable across the sites, but fish populations were either stable (at two sites) or significantly enhanced (at one site) (Adamowicz and Roman, 2002). The larger, longer project by James-Pirri et al., has only published interim data sets (James-Pirri et al., 2003); a project report was due in 2004, but has been delayed while undergoing review by USFWS and USGS (the project sponsors). Reportedly, USFWS will use the findings of the James-Pirri et al. study to determine the Region-wide response to OMWM proposals.

### 5.7.3 OMWM on Long Island

In the early 1980s, OMWM pilot studies were conducted on the salt marsh at Seatuck National Wildlife Refuge aimed to reduce mosquito numbers with minimal damage to the marsh community and to reduce dependency on chemical pesticides.

A baseline study was conducted by Cowan et al. to establish baseline data for selected ecological and hydrological parameters. The parameters included:

- the timing of mosquito breeding and larval densities
- resident and migratory bird usage
- vegetative composition and distribution
- soil invertebrate analysis
- nutrient levels relative to tidal cycles
- distribution and abundance of fish species.

Marsh hydrology and topography were also studied to define the primary inputs, outputs, and pathways of water in the Seatuck marsh system. The objectives of this baseline study were:

- to develop a general hydrological model of the marsh
- conduct experimental OMWM alterations suited to local physical and biological conditions
- evaluate the effectiveness of marsh alterations for mosquito control
- assess any environmental impacts resulting from experimental marsh alterations through comparison of baseline data to post-alteration data

(Cowan et al., 1986).

After two years of pre-project monitoring, OMWM alterations (ditch plugs) were implemented on a test plot at Seatuck and monitored for an additional two years. In addition to mosquito control, the OMWM design focused on redirecting freshwater inputs to the marsh from upland edges, improving tidal circulation between the marsh and Great South Bay, and providing a permanent habitat for native fish that commonly prey on larvae. The results of OMWM at Seatuck determined that mosquito production was reduced, but not eliminated, without any significant adverse impacts on the marsh (Lent et al., 1990).

After the completion of the OMWM project, the USFWS constructed a tidal creek to further restore this wetland. Most of this marsh no longer breeds significant numbers of mosquitoes, but one section, known as IS-74, continues to require regular larvicide applications. In addition, the reduction of *Phragmites* combined with OMWM techniques at the Seatuck NWR has resulted in a fivefold increase in shore bird use (R. Parris, LI NWR, personal communication, 2004).

Immediately following the Seatuck project was an effort at Mott Lane-Fireplace Neck Marsh. The project was designed in 1988 (Hruby et al., 1988), and implemented in 1989 (Sperry, 1992). No follow-up information on the project is available, although it is implied in Sperry that the project was successful at controlling mosquitoes, as the report proposed an expansion of the OMWM eastward onto USFWS lands. The plan called for use of ditch plugs, spur ditches, and selective ditch maintenance (Hruby, 1988).

These efforts evidently produced a report giving general guidelines towards best management practices in tidal wetlands for Long Island (Hruby, 1990). Although generic in nature, and intended to address all forms of wetlands management, the manual was pointed at OMWM implementation as a general mosquito management and preferred wetlands restoration tool. It defined specific conditions that made a salt marsh a good candidate for OMWM:

- More than 80 percent vegetated
- Excessive mosquito breeding
- Salinity in surface waters above 15 ppt
- Marsh surface flooding more than three times per summer

The manual also laid out pre-implementation monitoring to address these criteria. The preferred OMWM implementation, as the manual was based on the Seatuck National Wildlife Refuge demonstration project, was to create fish reservoirs and use ditch plugs, and so was a closed system. Post-project monitoring, including mosquito larvae surveys, ditch and pool dissolved oxygen, temperature, and salinity measurements, and a vegetation survey, was also described (Hruby, 1990).

Shortly thereafter, a general plan was produced for South Shore Mainland marshes. This anonymous plan, called the South Shore Mainland Marshes Focus Area Plan, was based on principles of the North American Waterfowl Management Plan of 1986, which called for the protection and management of priority wetlands habitats to support migratory birds. The importance of salt marshes along the mainland of the South Shore, east of the Robert Moses

Causeway, made this area a target for improving the quality of the wetlands. The proposed mechanisms were:

- Acquisition

This involved the purchase of privately owned wetlands by NYSDEC, USFWS, Suffolk County, towns, villages, The Nature Conservancy, National Audubon, and Ducks Unlimited. In addition, it was proposed that a cooperative management approach be formulated among these landowners (along with NPS and the NYS Office of Parks, Recreation and Historical Preservation), under the lead of NYSDEC (using the mechanism of the Long Island Wetlands Act). The goal was 400 acres.

- Open Marsh Water Management

Although identified primarily as a mosquito management tool (and one that had been successfully implemented at Seatuck and Fireplace Neck), OMWM was also described as a bird habitat enhancement, as it had resulted in marsh restoration leading to a diversity of insects and invertebrates that were preyed on by shore birds, song birds, and water fowl. The goal was 2,000 to 3,000 acres.

- Habitat Restoration

The intent was to restore tidal flows, conduct impoundment management (including salt water level manipulation and the potential creation of new fresh water ponds adjacent to the salt marshes), vegetation management (such as control of *Phragmites*), and dredge spoil removal. The goal was 2,000 to 3,000 acres.

- Regulatory Legislation and Enforcement

Primarily, the intent was that violations of existing regulations should result in some form of mitigation, either directly where the violation occurred, or at another site but in furtherance of the overall Focus Area Plan.

The estimated costs, mostly associated with acquisitions, were $2 to $5 million. 50 individual sites were targeted (see Table 5-4, Figure 5-4) (Anonymous, 1991). It is not clear that the areas being considered were carefully quantified.

Table 5-4. List of Marshes Considered Under the South Shore Mainland Marshes Focus Plan

| MAP # | SITE NAME | MAP # | SITE NAME |
|---|---|---|---|
| 1 | Gardiners County Park | 26 | Mastic Beach Yacht Club |
| 2 | Isbrandtsen Preserve | 27 | William Floyd Estate |
| 3 | Thorn Preserve | 28 | Forge River |
| 4 | Scully Sanctuary | 29 | Mud and Senix Creek |
| 5 | Seatuck National Wildlife Refuge | 30 | Orchard Neck |
| 6 | Islip Nature Preserve | 31 | Terrell River |
| 7 | Heckscher State Park | 32 | Tuthill Point |
| 8 | Timber Point | 33 | West Cove including Chapman property |
| 9 | Pickman/Remmer | 34 | U.S. Coast Guard |
| 10 | Blankman LaSalle | 35 | Harts Cove |
| 11 | West Sayville Golf Course | 36 | Havens Point |
| 12 | Browns River | 37 | Little Seatuck |
| 13 | Namkee Creek | 38 | Seatuck Creek |
| 14 | Sconzo/Stillman Creek | 39 | East River |
| 15 | Swan River | 40 | Fish Creek |
| 16 | Mud Creek | 41 | Remsenberg |
| 17 | Dunton Creek | 42 | Tanners Lane |
| 18 | Koch property | 43 | Moneybogue Bay |
| 19 | Howell Creek | 44 | Quantuck Creek |
| 20 | on Bellport Bay west of Beaver Dam Creek | 45 | Aesops Neck |
| 21 | Fireplace Neck | 46 | Phillips Creek |
| 22 | Wertheim National Wildlife Refuge | 47 | Davis Creek |
| 23 | Smith Point Marina; Shirley Basin | 48 | Weesuck Creek |
| 24 | Johns Neck Creek | 49 | Shinnecock Indian Reservation |
| 25 | Pattersquash Creek | 50 | Dupont Sanctuary |

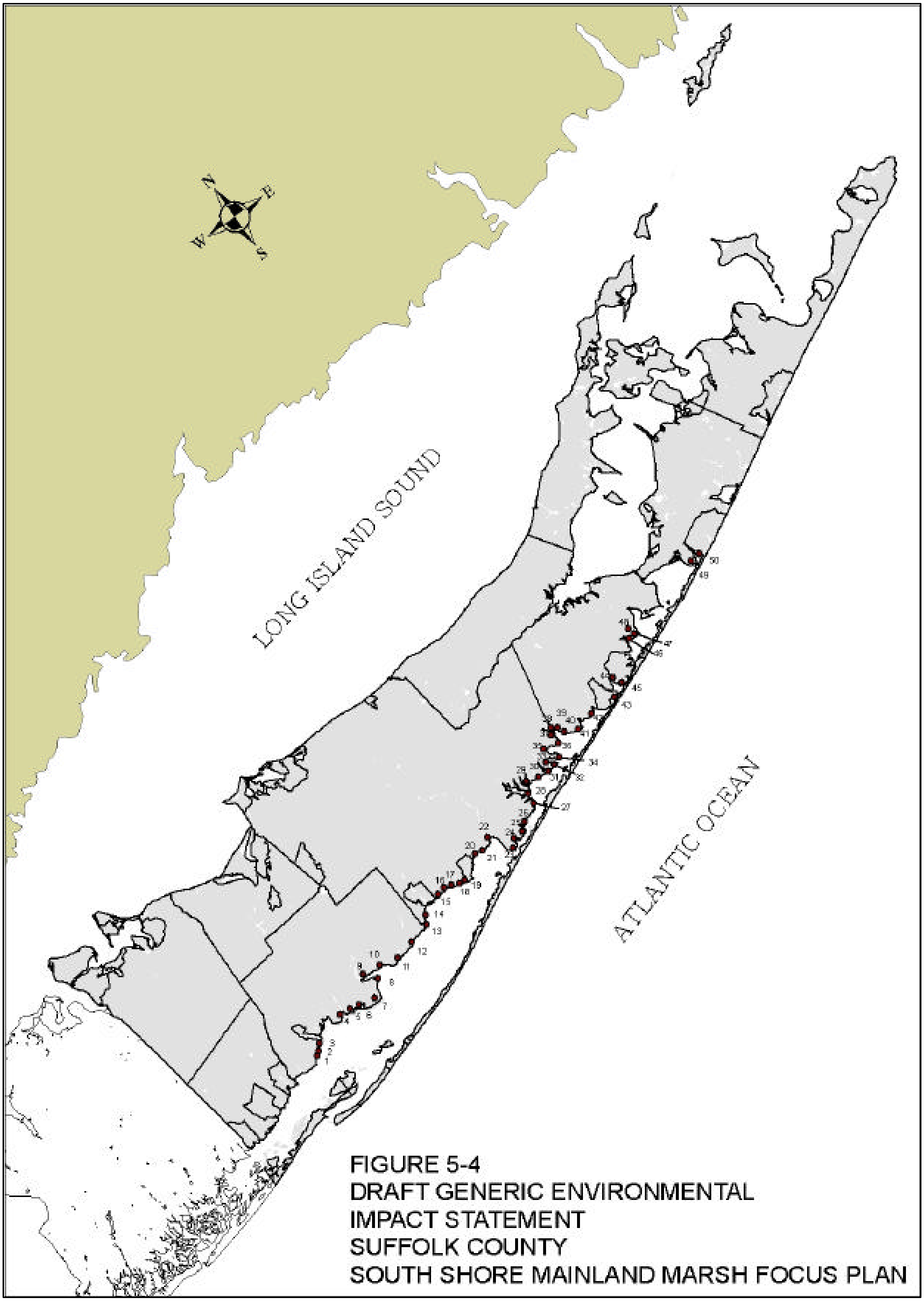


FIGURE 5-4
DRAFT GENERIC ENVIRONMENTAL
IMPACT STATEMENT
SUFFOLK COUNTY
SOUTH SHORE MAINLAND MARSH FOCUS PLAN

*Salt Marsh Restoration and Monitoring Guidelines* resulted from the Seatuck project, and was produced through a joint effort between NYSDOS and NYSDEC (Niedowski, 2000). The document serves as a framework for New York salt marsh restoration activities, including planning, design, implementation, and monitoring for restoration projects sponsored by municipalities. The goal statements for habitat restoration in New York State are summarized as follows:

- To the greatest extent practicable, achieve functional, community, and/or ecosystem equivalence with reference sites when undertaking restoration.
- Restore critical habitats for priority fish, wildlife, and plant species, including those listed as threatened, endangered, and of special concern by Federal and State governments, and species of historical or current commercial and/or recreational importance in New York State.
- Plan and implement restoration initiatives using a regional perspective to integrate and prioritize individual restoration projects and programs.
- To the extent practical, use historical acreages, proportions, and/or spatial distributions to prioritize habitats from a state or regional perspective.
- To the extent practical, ensure where appropriate that historical acreages, proportions, and/or spatial distributions of priority habitats are restored and preserved.

Two desirable OMWM techniques described in the manual are closed systems and semi-tidal systems. According to the guidelines, closed systems should consist of shallow ponds and pannes ranging from two to 18 inches deep, sump ponds ranging from 30 to 36 inches deep, and pond radial, spur ditches approximately 30 inches deep. Ponds with gentle slopes are recommended in areas where mosquito breeding is evident. More shallow areas may be constructed in a pond for shorebird foraging areas. Excavated spoil resulting from pool and ditch creation is recommended to be used to raise the bottom of ditches, and for plugging ditches. The use of rotary ditching equipment is advised to minimize the impacts of spoil disposal. The semi-tidal systems are described as consisting of 30 inch deep ditches with sills that are only partially tidal. A sump pond and connector ditch system is recommended for semi-tidal systems as well (Niedowski, 2000).

The Long Island Wetlands Restoration Initiative, a cooperative management approach espoused by USFWS, NYSDEC, and SCVC, under the leadership of Ducks Unlimited, conducted an OMWM in the Flanders Wetland Complex. Work was conducted by Ducks Unlimited and USFWS on USFWS land, and by SCVC on Suffolk County parkland. NYSDEC and Suffolk County Parks were involved in project planning, and NYSDOS was also involved in the review process. The project involved the installation of ditch plugs in sections of Goose Creek, Birch Creek, and Mill Creek in March, 2001. Control sites were established at another section of Mill Creek, and wetlands east of Mill Creek. Ditch characteristics were carefully reviewed prior to project initiation, and photo documentation of pre-project conditions was made. The ditch plugs and the ponds created by the plugs were carefully described, post-implementation. The plugs, which were generally short (the plugs at Goose Creek were described as being longer, 10 to 20 feet in length), revegetated in Spring, 2001. Killifish and grass shrimp were observed in the ponds, and fiddler crabs colonized the plug surfaces. The methods used for bird observations were reported, but the results were not presented in the report. The report closed by noting that monitoring of the site would continue under the USFWS Region 5 effort (Kessler, 2002) (see just below).

The USFWS Region 5 study included the following Long Island sites:

- Flanders (two sites, 6.4 hectares total size), plugged in 2001
- the western part of Wertheim National Wildlife Refuge (8.5 hectares), plugged in 1997
- the eastern part of Wertheim National Wildlife Refuge (8.5 hectares), plugged in 1998
- Sayville (9.4 hectares), plugged in 1998

(James-Pirri et al., 2001; James-Pirri et al., 2002)

As part of the development of the Management Plan, CA personnel observed some of the local OMWM sites in the spring of 1994. Sites visited were West Sayville County Golf Course, Fireplace Neck in Islip, Seatuck National Wildlife Refuge, and the William Floyd Estate in Shirley.

At West Sayville, ditch plugging was done under the direction of Robert Parrish (USFWS). The typical ditch plug was constructed with a small piece of plywood, about three feet long, placed in the ditch with marsh material placed behind it. A small fish reservoir was a common feature just behind the plug. Over time, the plugs became vegetated, and the plywood was no longer visible. Many of the plugs were intact, and caused saltwater impacts to the marsh. The most noticeable impact was an increase in vegetation diversity, including *S. patens* grasslands, especially towards the uplands, and many large ponds, moreso towards the bay. Many killifish were visible in the ditches and ponds. There were many birds using the marsh, especially in the areas of standing pools. These pools tended to be only a few inches deep. *Phragmites* is abundant in the upper marsh, but appears to be dying back where ponded water has been maintained. A comparison of older aerial photographs to current conditions showed no major changes in the marsh. However, because the marsh no longer drains at low tides, former mudflats have become standing pools. Birds observed during the visit included:

- black duck (in shallow panne)
- green-winged teal (in shallow panne)
- Canada geese (in shallow panne)
- gulls (in shallow panne)
- greater yellowneck (in shallow panne)
- great egret
- snowy egret
- osprey

As part of a multi-agency cooperative venture, in the winter of 1999, a pilot OMWM project was conducted at the William Floyd Estate, which is managed by NPS as part of FINS. The OMWM consisted of plywood sheets and associated plugs consisting of organic matter from the grid ditch substrate. This project's initial activities took place over the course of 10 days, on 200 acres. Pannes or ditches that largely drained at low tide are now linear ponds, and fish, crabs, and invertebrates are now observed in areas that once were breeding mosquitoes. There were two "hot spots" on the marsh, formerly, where an appreciable amount of mosquito breeding was taking place, that no longer exist (R. Stavdal, NPS, personal communication, 2004).

According to Richard Stavdal (Unit Manager, NPS), the impact on the bird population has been noticeable. Migratory wading birds now find more food sources. Water fowl can use the flooded salt marsh for brooding, feeding and resting. In addition to the formation of linear ponds, salt pannes began to form in lower elevations of the marsh. The impounded, high salinity waters associated with the OMWM have caused a noticeable decrease in *Phragmites* stands. The ponds created by this project stopped increasing in size after four years, and *Phragmites* are not found in or around these ponds.

### 5.7.4 Reported Effects of OMWM

#### 5.7.4.1 On Mosquitoes and Mosquito Control

According to Ferrigno et al. (1975), when properly designed, OMWM should achieve greater than 95 percent reduction in mosquitoes. In a comparison of mosquito emergence in an unaltered marsh and an OMWM-treated marsh, significantly fewer mosquitoes were observed emerging from the OMWM-treated marsh. Prior to that study, Ferrigno (1970) had found that mosquito production fell from 10,000 mosquitoes per square foot to less than a thousand in the first year after OMWM, to zero at the same site in the second year.

In addition to allowing fish predation on mosquito larvae, OMWM is likely to interfere with the hatching cycle of mosquito eggs. Water management for mosquito control is based upon three fundamental principles: removal of excess surface water; increasing the amount of standing water; and increasing the movement of water (Shisler, 1978). The numbers of mosquito larvae that survive to pupate as adults on the marsh surface are negatively correlated with both tidal inundation and the number of killifish or other fish species that will prey on the larvae (Buchsbaum, 2001).

Numerous studies have shown that OMWM alterations resulted in a decrease in the amount of mosquito breeding locations. Marshes in Delaware, Florida, Rhode Island, New Jersey, and Maryland subsequent to OMWM reported success in the reduction of mosquitoes (Wolfe, 1996; Ferrigno, 1970; Daiber, 1974; Lesser and Saveikis, 1979; Hruby et al., 1985). Dale and Hulsman (1990) noted that one impact of OMWM is to reduce the drying out of potential mosquito breeding locations, which disrupts the cycle events needed for successful breeding.

During the first season of OMWM, a Massachusetts marsh had significantly lower numbers of mosquito larvae and pupae when compared to adjacent control sites (Hruby et al., 1985). In New Jersey, for every 1,000 acres of the marsh treated with OMWM, it is estimated that 40 to 60 billion mosquitoes will be eliminated annually for the life of the OMWM system (Ferrigno and Jobbins, 1968). Similar reductions were reported in North Carolina, Massachusetts and California marshes subject to OMWM (Wolfe, 1996). After the first year of OMWM alterations at two New Jersey marshes, mosquito breeding was eliminated for five years at one marsh, and two years at the other marsh (Ferrigno, 1970). OMWM alterations to a Connecticut marsh in 2001 resulted in the elimination of mosquito breeding in the trenches and ponds; however, larviciding was required in surrounding areas (Wrenn, 2002). A ninety-five percent reduction in mosquito larvae and pupal population was observed at Fairhill marsh in New Hampshire following the re-designing of existing pannes as OMWM pools to increase the amount of permanent water on the marsh (New Hampshire Coastal Program, 2004).

Not every OMWM is reported as a success at controlling mosquitoes. Fresh water mosquito breeding occurred in lower marsh areas at Seatuck Refuge following OMWM alterations. It was thought that the alterations, possibly, were preventing rain water from draining off the marsh surface, and that salinity may have decreased in marsh depressions enough for them to become a favorable habitat for fresh water mosquitoes. The OMWM did not reduce the average number of female mosquitoes collected in the refuge light trap. Prior to OMWM alterations between 1986 and 1988, the average females per night varied between 28.8 and 34.5. After OMWM alterations in 1989 and 1990, the average number reached 41.7 and 32.2 each year, respectively (Guirgis, undated).

A study conducted in Ocean County, New Jersey, demonstrated that water management can result in significantly lower numbers of larvicide applications. Water management alterations conducted on three separate marshes eliminated over 93 percent of the acreage of mosquito breeding (Shisler et al., 1979). As discussed above, larviciding has been eliminated on marshes treated with OMWM in Connecticut, and decreased on OMWM-treated marshes in Florida. The experience in Ocean County, New Jersey (as related to CA), has also been very positive, although the need for some larviciding is usually not entirely eliminated there through OMWM.

Overall, the major benefit cited for OMWM, beyond reducing ecological effects associated with standard water management, is to substantially reduce the need for larviciding. In fact, Wolfe (1996) spends some time marshalling evidence that OMWM can be justified economically merely in terms of the savings associated with less frequent larvicide applications. This appears to be the case for the very large marshes of New Jersey, especially, where large amounts of chemicals need to be applied in the absence of water management, but the single capital investment in water management may reduce the amounts used by 90 percent or more.

There is little explicit evidence of reductions in adulticide use. In one example where adulticiding was explicitly discussed, Montgomery (1998) reviewed the impact of OMWM at Rumney Marsh in Massachusetts. Prior to its implementation, mosquito abatement focused primarily on the use of adulticide. In the 1990s, OMWM techniques were applied to restore the degraded state of the marsh. As a result, mosquito populations decreased and the need for adulticide treatments became rare. The remaining mosquito breeding areas were managed by hand larviciding. Theoretically, by reducing the amount of mosquito breeding, the need for control of mosquitoes to enhance quality of life and also to reduce bridge vectors capable of transmitting disease should be reduced.

#### 5.7.4.2 On the Vegetated Marsh

Dominant plants characteristic of high salt marsh areas include *S. patens*, *Distichlis spp.*, and short-form *S. alterniflora*. *I. fructesans* and *B. halimifolia*, *Solidago spp.* and *Phragmites* are typical plants found along the perimeter of the high salt marsh (Nixon, 1982). OMWM efforts focus on the high marsh, and so it is most probable that impacts will be found there.

One specific intention of installing an OMWM, at many sites, is *Phragmites* control. Sulfides, anoxia, and salinity are known stressors to *Phragmites* growth (Bart and Hartman 2002). Because of the presumed impacts on *Phragmites* by increased salinity, one method of remediating a *Phragmites* invasion is to increase tidal flushing to impacted marshes. Another is to intercept fresh water inflows that decrease salinities. The implementation of OMWM perimeter ditches in the upper edge of a salt marsh has been used to prevent further *Phragmites* encroachment (Buchsbaum et al., 1998). Herbicides are often used in conjunction with other efforts, such as controlled burning, to remove *Phragmites*. However, most marsh managers believe these practices will not be successful as long-term strategies unless the underlying site hydrology is changed at the same time that spraying and burning occur (Mitsch, 2000).

On-going *Phragmites* management efforts in Connecticut have focused on changing the environmental conditions favoring *Phragmites* through OMWM techniques. In 1985, in Clinton, Connecticut, a cooperative program was begun between CTDEP and the Mosquito Control Unit in an effort to restore degraded wetlands on the Hammock River by implementing OMWM. The plan focused on restoring tidal flushing during the summer to maximize the emergent vegetation and minimize the conversion of salt marsh to open water. After the first three years of the program, the annual height reduction in *Phragmites* averaged one foot. By the fifth and sixth year, *Phragmites* stopped growing, dead shoots no longer persisted, and exposed peat was colonized by salt marsh grasses. Targeted birds, such as egrets and water fowl, increased as a result of the program (Dreyer and Niering, 1995).

In 2000, Connecticut Wetlands Habitat and Mosquito Management Program installed OMWM ponds on a marsh dominated by *Phragmites* in an effort to restore marsh vegetation. The *Phragmites* stands were initially sprayed with herbicide and then mulched. Five OMWM ponds were installed and several old mosquito ditches were plugged (Capotosto, 2000). The results have been favorable, in that *Phragmites* has not been able to re-infest the marsh (Paul Capotosto, CDEP, personal communication, 2004).

Observations made by CA of Long Island marshes where ditch plugs were installed suggest they can be effective against *Phragmites*. Personal communications from Susan Adamowicz (USFWS, 2004) indicate that has also been the case at Rachel Carson National Wildlife Refuge in Maine.

Most OMWM implementations will not substantially alter the marsh surface elevation or restrict surface water movements. Therefore, there should be no shift in the overall distribution of wetlands vegetation (Wolfe, 1996). Changes in marsh resources are most affected by altered hydrologic patterns and spoil deposition. If the water table of a marsh is excessively lowered, marsh shrubs will likely inhabit the area because of the drier habitat. In addition, if spoil piles are placed on the marsh surface, higher successional plants (i.e., *Iva*) are likely to cultivate on the piles (USFWS, 1998).

Increasing tidal flows in a salt marsh was found in one short-term (one season) study to have negative impacts on all plants in the marsh. This is true for invasive species such as *Phragmites*, but also true for halophytes in the *Spartina* family. This may be due to increased inundation durations (Konisky and Burdick, 2004). Generally, however, productivity increases are linked to halophyte exposure to tidal flows (Odum, 2000).

According to Mitsch (2000), salt marshes that have been altered to reestablish the hydrologic connections of coastal ecosystems to adjacent bodies of water will reestablish salt-tolerant vegetation, such as *Spartina spp*. Lesser (undated) reached the same conclusions. In addition, Lesser noted that a single tidal ditch transversing a low *S. alterniflora* salt marsh will have no adverse effect on marsh vegetation, and in fact, marsh faunal diversity can increase. However, when a network of open tidal ditches passes through a high (*S. patens*) marsh, this can lead to changes in vegetation.

Marshes on Maryland's eastern shore experienced a vegetation shift toward a high marsh after the installation of open ditches. Drainage associated with the open ditches may account for Maryland's high marsh vegetation shift. In Delaware, wherever OMWM techniques were implemented and the water table dropped five inches or fluctuated widely as in open-ditched high-marsh areas, *Baccharis*, *Iva* and other drier-soil plants such as *Pluchea purpurascens* invaded the ditched area (Daiber, 1986).

However, vegetation changes that do occur with OMWMs may not extend throughout the marsh. A Maryland study showed that *I. frutescens* rapidly colonized a marsh that had been treated with an open ditch system, but did not occur in adjacent closed or water controlled sites (Whigham et al., 1982). When high marsh grid ditches are kept open to daily tidal exchange, *S. patens* is often converted to a mixture of *S. alterniflora* and *S. patens* along the edge of new open ditches (USFWS, 1998).

Ferrigno (1970) concluded that the standard New Jersey OMWM technique encouraged a shift in vegetation to that of a low-marsh. For example, a mosquito ditched marsh in Tuckerton, New Jersey, shifted toward a low marsh community after OMWM implementation (Shisler and Jobbins, 1977a). This shift was attributed to the increase of tidal circulation, and possible nitrogen fixation in the ditched marsh. On the other hand, CA's tours of OMWM sites in Ocean County, New Jersey, generally found no shift in overall vegetation communities from the pre-operational vegetation conditions.

A four-year study at the Seatuck NWR, Long Island, concluded that while vegetation composition in some plots within the altered marsh changed from year to year, there was no clear relationship between observed vegetation changes and OMWM alterations. The analysis was not able to associate the vegetation shifts to any contemporaneous hydrological and salinity changes induced by OMWM alterations to the marsh (Lent et al., 1990).

Ferrigno (1970) reported a reduction in the amount of short-form *S. alterniflora*, as well as *Salicornia* and *Cladophora spp.*, on a New Jersey marsh immediately following OMWM alterations. Increased tidal circulation and the removal of stagnant surface sheet water, which sometimes have been found to promote the growth of these types of vegetation, were thought to be the reason for this vegetation change. No changes in the amount of salt hay grasses *Distichlis* and *S. patens* were reported; increases in the area of widgeon grass (*Ruppia maritime L.*) and sea lavender (*Limonium caroliniamm Walt.*), both beneficial food sources for water fowl, were reported. An increase in the occurrence of tall-form *S. alterniflora*, bassia (*Bassia hirsuta L.*), sea-blite (*Suaeda linearis Ell.*), sea rocket (*Cakile edentula Bigel*), slender leave aster (*Aster tenuifoluis L.*), saltmarsh aster (*Aster subulatus Michx.*), smartweed (*Polygonum aviculare L.*), saltwort (*Salsola pali L.*), and saltbush (*Atriplex harta L.*) were noted near the ditch edges.

Upon restoring tidal flow to a New England salt marsh, the amount of bare area increased as a result of the removal of a small berm, and from the mechanical equipment used to create OMWM pools (Roman et al., 2002). As vegetation (*S. patens*, *S. alterniflora*, and *Salicornia*) colonized the marsh, the relative cover of bare areas decreased during the second year of restoration.

Following the plugging of ditches at Granite Point Marsh in Maine, high marsh *S. patens* declined after one growing season due to the increase in water cover on the marsh (Adamowicz and Roman, 2002). However, no initial change in vegetation was observed at Moody Marsh, Maine, subsequent to ditch plugging.

CDEP reported good recovery of vegetation following OMWM, with revegetation usually occurring by the end of the first year. The Connecticut intent is (generally) to increase surface water areas in grid-ditched marshes, and so CDEP expects there will be some decreases in the overall number of acres covered by plants (Wolfe et al., undated).

CA's observations in Ocean County, New Jersey, where spoils are cast out over the marsh surface, are that bare areas can persist for several years. However, installations past the initial stage of recovery appear to be thickly vegetated. Ocean County personnel reported that there was no marsh retreat due to the construction activities. Observations of Long Island marshes treated by ditch plugs show that some vegetation can be lost due to the expansion of surface water area; however, the expansion of the surface water area appears to stop after several years.

The re-establishment of water in the interior marsh areas does not appear to lead to trends of increasing erosion of the marsh surface or other kinds of losses of marsh vegetated areas. In fact, after two years of restored tidal exchange on the New England marsh, vegetation was noted to be developing toward the typical pattern of a southern New England marsh (Roman et al., 2002). An impounded freshwater marsh in New Hampshire showed subtle changes in vegetation only two years after tidal restoration was implemented, with expectations that changes in vegetation will continue (Burdick et al., 1997).

In Connecticut, where tidal restrictions are often addressed together with the installation of OMWM, vegetation recovery was noted to be an on-going process after tidal flow was reintroduced to the marsh (Sinicrope et al., 1990). A 40-year process of vegetation change was observed by Rozsa (1995), where areas of intertidal flats became a low marsh *S. alterniflora* community on a Long Island Sound marsh after the removal of tide-restricting gates.

Concerns are sometimes raised regarding the creation of open water on salt marshes, as often is intended in OMWM. These comments often cite work by Kearney regarding the health of marshes, based on the percentage of water detected on the marsh by satellite imagery. This classification scheme was generated by research in the Chesapeake Bay, especially at Blackwater National Wildlife Refuge, where 50 percent of the vegetated marsh was lost over the 20th Century. The proximate cause of the losses here and at other sites (although not of as great a magnitude) appear to be channel and pond enlargement, and the creation of in-marsh rotten spots and salt pannes, and appears to relate to rising sea levels that locally are two to three times the world-wide average of one or two mm per year. Vegetated marsh is turned into mudflats. The underlying cause of the rapid local sea level rise appears to be subsidence due to agricultural groundwater withdrawals. This is abetted by the high organic content of interior marsh sediments, which, when starved of sediments from other anthropogenic alterations of the environment (such as dredging, and also local road construction across wash-over zones that also impedes tidal energy into the marsh), can become sulfide-poisoned, even with erosion of upland agricultural sediments (Stevenson et al., 2000).

In addition, observations made in the Chesapeake Bay have also been cited as reasons that island marsh systems may be most in peril from increasing sea level rise rates. This may be partially due to the lack of upland sediment inputs for such systems. In the Chesapeake Bay, the Bay was found to be experiencing a sea level rise of three mm/yr in the mid-1980s. Marsh accretion rates were found to be less than this at sites experiencing major areal losses (Stevenson et al., 1986). At Bloodsworth Island, a major research site, three mechanisms were found to be causing marsh loss. These were:

- Perimeter erosion by wave action
- Channel formation and subsequent enlargement
- Interior pond formation and expansion

Over one-quarter of the island's area was lost between 1849 and 1992, most of which occurred due to perimeter loss. Ponds and channel widening caused most interior marsh losses prior to 1942. A brief period of accelerated sea-level rise (to seven mm/year from 1930 to 1948) was thought to be linked to the creation of new, non-channel ponds (although it may also be an artifact relating to the non-inclusion of small, non-connected ponds in older maps). Non-channel ponds have also been found to be growing in area in other, mainland marshes. The ponds appear to form due to waterlogging of vegetation, almost exclusively *Juncus roemerianus* (black needle rush). *J. roemerianus* is a high marsh plant, and so cannot withstand daily tidal inundation. If the underlying substrate fails to maintain itself against sea level rise, there will be more frequent inundations of the plants, leading to die-backs. Continuing losses in interior wetland areas appear to be linked to new pond formation, rather than expansion of existing ponds (which appear to be fairly stable in size) (Downs et al., 1994). Because of this, some have interpreted these results as suggesting the addition of interior ponds may lead to enhanced marsh destruction. As discussed above, others seem to believe that the overall cause of marsh drowning in the Chesapeake Bay is groundwater withdrawals (Stevenson et al., 2000). It may be that pond creation can contribute to the loss of vegetated areas, however.

Marshes in Delaware have similarly suffered from drowning events. However, these had a different genesis. Shoreline marshes in Delaware tended to have been diked and ditched, often in colonial times, to encourage salt hay production (*Spartina patens*, the signature high marsh plant). Diking interrupted natural tidal cycles, and ditches carried any tidal influxes off quickly, making for infrequently flooded substrates. Marsh surface subsidence (from compaction and sediment starvation) and sea level rise meant that if a dike failure occurred in the past half-century, the marsh flooded to such a degree that the vegetation was lost, and there was usually catastrophic loss of vegetated marsh through erosion. Natural recovery has often been slow (three to four decades), requiring colonization by *Spartina alterniflora* when successful, but marked by invasive *Phragmites* monoculture in many cases. Because of the depressed level within the dikes, standard OMWM projects can result in ponds that grow beyond design bounds. To address that issue, recent projects have incorporated the creation of a higher order drainage structures. Key elements are major tidal channels that, near to the estuary, contain little sinuosity, but greater sinuosity away from the estuary. This design promotes better tidal drainage, mimics the structures found in natural marshes, and tends to allow for the creation of more in-marsh channels through head-cutting. A major goal of these projects is to stimulate and increase fish use of the marshes, which is intended to restore ailing local fisheries (Weinstein et al., 2000b).

#### 5.7.4.3 On Biota

OMWM has little or no adverse impact on water fowl habitat, and is generally thought to have positive effects. OMWM ponds are expected to provide a feeding and resting area for migrating water fowl. Submerged vegetation found in ponds offers an important food supply for wintering ducks (Widjeskog, 1994). Most reports find that marshes altered with extensive networks of pools are utilized by larger bird populations than grid-ditched marshes that have few pools (Reinert et al., 1981; Clarke et al. 1984, Brush et al., 1986, Adamowicz and Roman 2002). Thus, OMWM ponds can improve or restore water fowl habitat. Montgomery (1998) concluded that the OMWM alterations at Rumney Marsh in Massachusetts, which included the construction of ponds, dramatically enhanced or restored wading shore bird and water fowl habitat.

Erwin et al. (1994) recommended that the emphasis should be on fewer numbers of large OMWM ponds, “large” defined as being greater than 0.10 hectare. They should be constructed with shallow basins (less than 15 cm. deep). They should have sloping sides. This design is preferred over a larger number of small, deeper ponds to maximize water fowl marsh use. Erwin et al. showed that, one year after construction, most water bird species used the OMWM ponds more often than other water bodies on the marsh, such as natural tidal ponds, creeks, and old ditches. However, when OMWM ponds were located near impoundments, black ducks (*Anas rubripes*) and other water fowl such as American wigeon, gadwall, and northern pintails, were more likely to utilize the impoundment for nesting, and to use the impoundment during the autumn and winter compared to the OMWM ponds. The large open water areas and submerged aquatic vegetation were thought to be the reason why the impoundments were favored by water fowl.

At the Egg Island marsh in Cumberland, New Jersey, water fowl use did not differ from the control marsh, with the exception of greater snow goose (*Chen hyperborean*) and Wilson snipe. Snow goose and snipe numbers were considerably less at the OMWM treated marsh than at the poorly-drained control area (Ferrigno, 1970).

It has been suggested that OMWM does not significantly impact invertebrate populations (Wolfe, 1996). This is perhaps the greatest food source for non-water fowl birds, and so suggests that bird populations should not be significantly impacted. However, if vegetation patterns are altered, including the loss of woody plants from the high marsh and banksides, birds that rely on those plants for cover may reduce their use of the marsh. Ferrigno (1970) noted that when the marsh ecology is changed by removing the influence of tides, or by blocking the tidal influx by dikes, numbers of clapper rails (*Rallus longirostris crepitans*) and their major food source, fiddler crabs (*Uca spp.*), may decline.

OMWM has few immediate adverse or beneficial impacts on salt marsh birds in areas that formerly were ditched (Brush et al., 1986; Grant and Smith, 1998). Although the study conducted by Brush et al. (1986) concluded that OMWM had little impact on bird numbers on a marsh that was previously ditched and converted to an OMWM system, the data were a little more ambiguous. During the first year of monitoring, shorebird numbers increased, but then declined in subsequent years. This decline was thought to be the result of vegetation growth on spoils. The spoils initially provided accessible and plentiful foraging for invertebrates by the birds. However, as the vegetation grew through the spoils, invertebrates were harder to obtain. Brush et al. suggested that bird numbers were more closely related to the number of pannes on a marsh rather than whether it was altered by OMWM, ditched, or remained natural.

OMWM techniques at the Seatuck NWR resulted in a fivefold increase in shorebird use (R. Parris, LI NWR, personal communication, 2004). Red-winged blackbird numbers, however, showed a decrease, from 55 before OMWM to less than 10 after alterations to the marsh (Lent et al., 1990).

Negative impacts to migratory birds were observed in a Massachusetts ditched marsh resulting from vegetation changes. Shrubs or exotic species invasion dominated the marsh vegetation, decreasing habitat use by shorebirds, wading birds, and aerial insectivores (USFWS, 1998). Although prey population is not reduced by ditches, Clarke et al. (1984) concluded that ditching can adversely impact bird populations by draining pools that are used for foraging.

Foraging areas within ditches are further limited by their narrow width. OMWM, by restoring open waters on the marsh, should not have these kinds of negative impacts (although ditches are not always eliminated in OMWM applications).

Juvenile fish often utilize salt marshes for the abundant food supply and to seek refuge from predation (Deegan et al., 2000). Wolfe (1996) demonstrated that tidal circulation, enhanced by ditches, replenishes the fish that consume mosquito larvae back into the high marsh pools. At a previously extensively ditched marsh in New Hampshire, the ditches drained the marsh surface of deep, permanent pools of water. The amount of permanent open water on the marsh was increased in 1999 due to restoration efforts, resulting in an increase of mummichog and stickleback populations, fish that accessed over ninety percent of the restored marsh (New Hampshire Coastal Program, 2004).

Fish responded immediately to a New Jersey marsh restoration project which involved the creation of fairly large subtidal creeks. Most population structural parameters, such as seasonal occurrence, average size, and size frequency distribution, were similar to those of the reference marsh creeks. The abundance of fishes was invariably greater in the creeks of the restored marsh. This may be related to greater food availability, which may be a short-term response by selected prey species and result in an influx of fish to the creeks. Considerable variation in the abundance of some fish species resulted from the OMWM alterations over a period of several months. Significant decreases in the mean number of fish per sample and the percent frequency of occurrence were observed for *F. luciae* and *L. parva,* and an absence of *M. beryllina* (Able et al., 2000).

Other OMWM-treated marshes in New Jersey had tidal flows and fish assemblages similar to those of unaltered marshes (Talbot et al., 1986). This study showed that if shallow, non-vegetated potholes are deepened or enlarged to create a permanent vegetated pond or system of ditches, relative and absolute abundances of mummichogs and spotkin killifish will likely decrease, and sheepshead minnows, inland silversides, and rainwater killifish will increase. Although these four typical killifishes all prey on mosquito larvae, mummichogs and spotfin killifish will occur in greater abundance in shallow areas and the larvae and juveniles will move about on the top of the marsh more readily (Talbot and Able, 1984). Therefore, the fishes that prefer the top of the marsh are potentially more important mosquito predators than the fishes that favor deeper pond habitats (Talbot et al., 1986).

Changes in fish species composition occurred in the Seatuck marsh subsequent to OMWM implementation. Salt marsh fish species increased significantly, and fresh water fish species decreased two years following OMWM completion as a result of the increase in marsh salinity (Lent et al., 1990).

Marsh alterations, such as ditching, do not have marked effects on soil invertebrates (Rockel, 1969; Shisler and Jobbins, 1975; Lesser et al. 1976). However, the ditching of a marsh will impact other species. In a ditched marsh where the water table level dropped five inches, muskrats were observed departing the area (Daiber, 1986). The same observation was made by Stearns et al. (1939). Stearns et al. observed that effective ditching of a Delaware marsh for mosquito control lowered the water table level, changed vegetation, and, as a result, adversely impacted the welfare of the muskrat populations that previously inhabited the area.

At two marshes treated with OMWM techniques, Ferrigno (1970) reported increased numbers in fiddler crabs, ribbed mussels, and blue claw crabs. Salt marsh snails were found in fewer numbers when compared to control sites. An increase in amphipods was noted on the lower cordgrass at one marsh, but not at the other marsh.

Romanowski (1991) conducted a study pertaining to the use of an altered marsh by meadow vole (*Microtus pennsylvanicus*) in the months following management. Romanowski's study concluded that with respect towards OMWM, the size of the *Microtus* populations seemed to have been a function of the revegetation process following marsh management. This study showed that in a quickly revegetated marsh, *Microtus* populations increased more rapidly then compared to a slower revegetating marsh.

#### 5.7.4.4 Tidal Creek Functionality Issues

Tidal restrictions negatively impact salt marsh ecosystems (Burdick et al., 1997). According to Ferrigno et al. (1975), when daily tidal action is blocked, organisms important to the tidal marsh nutritional web are considerably impacted. This is why almost all OMWM installations use tidal flows as part of the water management regime. Full ditch plugs do not emphasize daily tidal flows as part of the water management efforts. OMWMs using full ditch plugs do require intermittent inundations, which are received through spring tides and/or storms (Shisler, 1978). A trade-off is created. There are water table increases and the retention of water in the ditches, which should create ponded areas, for example, where plugs are used. These are deemed to be more beneficial to the overall health of the marsh, and to meet the aim of the restoration effort, than the benefits associated with tidal flows where plugs are preferred. Conversely, emphasis on benefits associated with tidal flows leads to the use of more open systems.

Sills also restrict some tidal flows in the ditches. Again, the judgment made with a sill ditch OMWM is that retention of water and the potential water table restorations provide greater benefits than would be received if full tidal circulation occurred.

Water retention is expected to increase water tables. This can result in expansion of low marsh into formerly high marsh areas, reduce woody plant and *Phragmites* vigor, and restore drained ponds and pannes. In addition, retention of water in the ditches creates refuges for insectivorous fishes between high tides, and may increase water fowl habitat. These benefits need to be weighed against the impacts of tidal influxes. The consensus of opinion is that it is the importation of energy, nutrients, sediment, and biota on the tides that supports the vigorous marsh ecosystem (Odum, 2000). Limiting the tides, therefore, will have an overall impact on the health of the salt marsh, although that impact may not be significant.

#### 5.7.4.5 Overarching Ecological Factors

Typically, production taking place on a marsh may either accumulate in sediments as peat, decompose within the marsh, or be exported by the tides to more open estuarine and coastal waters (Nixon, 1982). Many salt marshes export materials to deeper waters, as shown by mass balance and stable isotopic studies (Valiela et al., 2000). Intertidal habitats, such as the marsh surface, depositional marsh edge, erosional marsh edge, and adjacent unvegetated intertidal flat, can serve as important sources of energy through exports to deeper water ecosystems, especially via predation by transient fish on marsh resident species (Cicchetti and Diaz, 2000). The edges of a tidal marsh tend to support a higher biomass and diversity of fishes and crustaceans than the marsh interior (Minello and Zimmerman, 1992; Baltz et al. 1993, Minello et al. 1994, Peterson and Turner 1994).

Shisler and Jobbins (1977b) demonstrated that ditched marshes release significantly lower levels of total organic carbon and particulate organic carbon than natural marshes. However, a study conducted by Cicchetti and Diaz (2000) concluded that trophic export from the depositional edge of a marsh has a significant contribution to deeper waters. Cicchetti and Diaz reported that blue crab use of depositional marsh edges was an important mechanism for movement of trophic energy off the marsh surface. OMWM, because it maintains many ditch surfaces, allows significant crab habitat to remain.

As originally conceived, marsh outwelling was believed to comprise the largely passive export of vascular plant detritus to the adjacent coastal system (see Odum, 1961; Teal, 1962). It is now known that edaphic algae comprise a major component of marsh primary production (Sullivan and Moncreiff, 1990). Further, these edaphic algae have been found to comprise up to 25 percent of suspended estuarine algae (i.e., phytoplankton), indicating that marsh algae can be readily transported off the marsh surface during tidal exchange (MacIntyre and Cullen, 1995). A second source of marsh export to adjacent is that of the soluble organics in vascular marsh plants (Alberts et al., 1988). During fall die-back of marsh grasses, up to 25 percent of the season's primary production is quickly released to the environment as dissolved organic matter. The fate of this material is not well known, but it most likely goes to bacterial secondary production as almost no other organisms could utilize dissolved food sources. In a well-flushed marsh system, much of this dissolved organic matter presumably enters the adjacent estuary and is consumed by bacterioplankton (Cai et al., 2003). For those OMWM systems that encourage tidal exchange, this process may be enhanced.

In terms of export pathways, it was traditionally believed that most energy transfer from marsh to adjacent ecosystems occurred by the direct export of organic matter. However, there is a growing body of evidence that energy transfer via non-permanent fish populations is a major pathway. Numerous pathways may be involved, including:

1) emigration of juvenile nursery fish after reaching maturity
2) seasonal marsh use by migratory estuarine fish
3) predation of marsh nekton by transient predatory fish

Larval and juvenile fish that inhabit salt marshes for sanctuary from predators and an abundant food supply commonly move to more open water habitats as they mature (e.g., croaker – *Micropogonias undulates*; spot – *Leiostomus xanthurus*), thereby transferring a significant biomass from marsh to estuarine and coastal ecosystems (Smith et al., 2000). Other fish move into marsh habitats in large numbers during seasonal onshore-offshore migrations (e.g., menhaden – *Brevoortia tyrannus*), which similarly accommodates large energy transfer through consumption of marsh meiofauna and algae (Cicchetti and Diaz, 2000). Finally, bluefish (*Pomatomus saltatrix*), striped bass (*Morone saxatilis*), and other coastal marine predators often hunt along marsh edges to take local nekton, thereby providing a trophic relay from local marsh communities to open marine ecosystems (Deegan et al., 2000). More recently, numerous stable isotope studies have furthered evidence for marsh energy export via fish, showing that many coastal fishes bear the isotopically light carbon signature of a *Spartina*-based food web (Melville and Connolly, 2003; Weinstein et al., 2000a).

The actual contribution of marsh outwelling to coastal ecosystems remains poorly quantified, but recent studies clearly show that earlier estimates up to 45 percent (Teal, 1962) are too high. This in large part because this process involves multiple sources of organic matter and multiple transfer steps from marsh to creek, estuarine, and finally coastal environments. Childers et al. (2000) specifically notes that many studies have been conducted at different spatial scales, from marsh creeks to the coastal ocean, making results difficult to compare. Furthermore, each of these factors vary significantly depending on a marsh's tidal regime and coastal physiography (Childers et al., 2000; Odum et al., 1979). Despite the complexities involved, most studies continue to suggest that the coastal ocean benefits from productivity leaked from salt marshes. For example, simple water column respiration studies in the coastal ocean have shown that these marine areas are often heterotrophic, meaning that the respiration of organic matter exceeds local primary production (Hopkinson, 1985). This requires an exogenus input of organic matter, for which salt marshes are a logical source. As EP Odum (2000) notes,

> Material and energy usually flow from concentrated hot spots to lower concentration areas. Salt marshes are hot spots of production, so it is logical to expect an outwelling of production and food energy.

Many fisheries studies also support linkages between marsh production and coastal harvests. Turner (1977) found that the regional yield of estuarine and coastal shrimp harvests were closely correlated with the area of coastal marsh, and similarly Teal and Howes (2000) found that declining fish catches in Long Island Sound since 1880 tracked the declining length of marsh-bordered coastline. Although neither of these studies provides any causative linkages, they echo a consistent body of literature supporting the model of salt marsh contributions to estuarine and coastal ecosystem. The putative increase in fish use of marshes associated with OMWM projects suggests that these projects will only enhance this important ecological function.

### 5.7.5 OMWM as Salt Marsh Restoration

According to the New York State Salt Marsh restoration Manual, tidal marsh restoration involves

> reestablishment of previously existing wetlands or other aquatic resource character and functions at a site where they have ceased to exist or exist only in a substantially degraded state.

Enhancement is defined as

> activities conducted … to achieve specific management objectives or provide conditions which previously did not exist, and which increase one or more aquatic function. Enhancements may involve tradeoffs”

which, if associated with habitat-type exchange, was called “often unacceptable.” It was noted that habitat manipulations involve a degree of risk, and so should be avoided (Niedowski, 2000).

Restoration has been defined as “the return of an ecosystem to a close approximation of its condition prior to disturbance” (National Research Council, 1992). Another definition of restoration is a process that regains an ecosystem composed of a physical environment resembling that under which the sought-for biota evolved. These are thought, because they once developed naturally, to be self-perpetuating. It is understood that necessarily water flows must be characteristic of the area, based on comparison to relatively undisturbed sites used as targets (Middleton, 1999). Mitsch et al. (1998) suggest that this approach can be strengthened through use of ecological "self-design." Species are introduced, and those that survive (a subset of those introduced) do so because they themselves are establishing the physical, chemical, and biological conditions that reinforce their success. This is contrasted with the more typical approach that Mitsch et al., describe as "botanical engineering" or "designer wetlands," where specific organisms (usually plants) are introduced, and success is judged on their survival rate.

The goal of restoring wetlands should be to establish a self-perpetuating vegetation regime. The system may be stable, or it may oscillate cyclically between two or more vegetation states, or the wetland may, due to natural succession, be unidirectional in its vegetation change. Because hydrologic zonation appears to drive wetland vegetation zonation, the hydrology of the site must be carefully established. Tidal access and inundation are controlled by the installation of channels and the relation of the sediment height to the hydroperiod. The complexity of these factors makes predictions difficult to rely on; it is more sound to use reference sites as a guide to potential results, and the goal should be system persistence, not establishment of a particular vegetation community structure (Niering, 1990).

Evaluations of wetlands restoration often call for "functional equivalency" between the restored wetland and some reference site. Most man-made wetlands fail these tests. By one measure, constructed wetlands have only 60 percent of the equivalent functionality of natural wetlands (Malakoff, 1998). Marshes constructed in Louisiana using dredge spoils clearly did not meet many equivalency tests, even six years after they had been installed, for instance (Edwards and Profitt, 2003).

Wetlands are open systems. This means that their functioning is impacted by intrinsic factors (those with their origin within the wetland) and extrinsic forces (those impinging on the system from outside). A wetland undergoing visible change may be maintaining equilibrium through ecological homeostatic maintenance. This can be addressed by viewing individual wetlands through a regional context, as short-term spatial change found in at one site may not be found when viewed at a regional scale. Some species need environmental change in order to persist, and so the notion has been proposed that asynchronous change in an ecosystem supports a greater diversity than a monotonic stable system. The difficulty in a managed system is that the level of system knowledge required to manage for this is not available. It is therefore suggested that success is more likely in systems where buffers are provided, spatial and temporal variability are enhanced, and reserve (unmanipulated) sites are provided for to serve as potential refugia (Willard and Hiller, 1990).

Measuring the success of a restored wetland should require much longer time frames than is usually considered, especially because persistence of the established system is probably the single most important aspect of success. It is recommended that vegetation types, above- and belowground biomass, and chemical and physical characteristics of the substrate be compared to some local reference (D'Avanzo, 1990). The difficulty is that structural similarity to a reference site does not necessarily mean that functional equivalence is linearly linked to the degree of structural similarity. It is very difficult to measure functionality well, and somewhat easier to measure wetland structural parameters (Zedlar and Lindig-Cisneros, 2000). In fact, in a situation where the creation of fish habitat was the goal, the best measure that could be determined was to reach a consensus of the involved experts (Weinstein et al., 2000b). However, if a nuanced comparison between certain structural elements is made, some conclusions regarding relative functional similarities may be drawn. It was suggested that a suite of monitoring measures be selected from parameters such as soil texture organic matter, and nutrient content, height distributions of indicator plants, invertebrate and fish population presence (with an emphasis of fish size), and topographical complexity (Zedlar and Lindig-Cisneros, 2000).

Removing artificial barriers to tidal flows at a site in Rhode Island was referred to as a salt marsh restoration. Increasing tidal connections resulted in a change in vegetation from *Phragmites* to *Spartina alterniflora* in only one season, and more fish usage of the marsh (the density of nekton in the restored marsh was statistically significantly greater than in an unrestored control site). However, overall species richness at the restored site was not greater than the control site where *Phragmites* persisted, and it was noted that at a Connecticut site, 12 years after tidal restoration, species richness at the restored marsh was not as great as at a natural reference site (Roman et al., 2002). However, fish use and vegetation recovery (as well as soil salinity increases) were immediately realized (as compared to pre restoration conditions, but also in comparison to reference sites) at tidal flow restorations in New Hampshire and Maine (Burdick et al., 1997). An overall study of nine restoration sites in Connecticut found that the degree of tidal flow across the marsh determined whether or not the marsh became comparable to reference sites; at one location, it took 15 years for bird populations to achieve similarity, and snail populations needed 20 years (Warren et al., 2002). Indications are that at many sites full functional equivalence may take decades to achieve (Fell et al., 2000). A comparison of algae species distributions in restored and natural salt marshes in North Carolina was made. Although the vegetation patterns in the marshes were similar, significant differences in algal speciation and biomass were found, even 28 years after restoration. These were linked to underlying sediment nitrogen and phosphorous concentrations (Zheng et al., 2004). Therefore, even though projects appear to be unambiguously successful, they do not always meet theoretical criteria established to determine valid "restorations."

However, restoration of wetlands without consideration of mosquito habitats will necessarily lead to greater mosquito breeding. Studies of new wetland construction in California and Arizona found that they were significant sources of mosquitoes. It seems clear that if wetlands are restored to increase natural values, most people will choose that mosquito-borne disease and other impacts should be minimized, if possible – a human value associated with restoration. It was noted that it is possible to distinguish between acceptable levels of risk, especially those to be experienced at home and those to be experienced when "in nature," and that those associated with the former are always lower than those associated with the latter. The Society for Restoration Ecology focuses on restoration as a process that returns functionality – not necessarily returning the ecosystem to an earlier state. Within that framework, it was noted that there may be a need for ecological restorations that control mosquitoes while improving conditions for other wildlife – so that there is the potential for improving natural values while maintaining important human values at the same time (Willott, 2004).

Buchsbaum (2001) found that OMWM had the potential for more uses than mosquito control. He suggested that the use of back channels could control *Phragmites* effectively, without the need for herbicides, and that skillful placement of spoils could provide nesting areas for shore birds (such as piping plovers) that require such disturbed areas. He also noted that pond sizing could be selected to enhance bird use of the marsh, and, as many have noted, there can be additional use by fish, including foraging by estuarine fish, following a project.

In certain areas, structural approaches to wetlands preservation have been adopted – that is, the use of levees, tide gates, weirs, and canal plugs to create buffers against waves or tidal flooding, control mosquitoes, create protected nursery habitats for fish or invertebrates, provide bird habitat, or to create a setting for stormwater or wastewater treatment. A review of these practices, which tend to be more dramatic than most OMWM techniques, noted that unintended (and often undesirable) impacts are associated with changes in marsh hydrology, effects may be irreversible, and although construction may not be difficult to undertake, managing or controlling impacts may be impossible. It was recommended that self-sustaining marshes that provide a range of functionalities should not be so changed, that restoration of former hydrological conditions is preferable to these sorts of alterations, that local marsh degradation causes be well understood prior to embarking on any projects, that projects should restore natural hydrology and functions as much as possible (at a minimum, maintaining periodic hydraulic connection to the surrounding ecosystem, and that they be well-monitored. Most of the modern-day applications of these structures are in the southern US, especially in Louisiana, and in inland waters. In New England, diking had clearly deleterious effects on marsh functionalities historically. Because OMWM promotes killifish, which was identified as a major means of ecological transfer of marsh productivity to the open estuary, the practice was identified favorably. Impoundments for waterbird habitat enhancement (and, in Delaware, mosquito control) were also identified as a somewhat common regional practice, but one that did not always achieve management goals, and also had some unanticipated negative impacts (Sanzone and McElroy, 1998). Therefore, OMWM may be distinguishable from other structural changes to salt marshes – and the difference may be that one class (OMWM) generally tends to have positive impacts, while the other class is not so clearly favorable for the environment.

Pools and pannes are naturally occurring features found in the high marsh of New England and mid-Atlantic salt marshes. Construction or creation of a marsh consisting only of emergent vegetation will be an incomplete approach to marsh restoration. Channels and other elements, such as pools and pannes, create the kind of diversity of wetland species, increased productivity, and better functionality, as well as leading to control of mosquitoes (Shisler, 1990).

A recent comparison of ditched and unditched marshes across New England found that unditched marshes had a greater number of ponds. The difference did not stem from the presence of tidal channels, as unditched marshes with creeks had more ponds than ditched marshes, and the difference was not an artifact of differing tidal height regimes (although more northerly marshes had more ponds than those in southern New England). The average pond size was approximately 200 square meters, and the average depth was 29 cm. Approximately nine percent of unditched salt marshes were composed of open water ponds (Adamowicz and Roman, 2005). Therefore, it is arguable that areas with open water percentages less than 10 percent may well be returned to a more natural state by augmenting the open water through channel and pond construction – as is the practice under OMWM.

Therefore, although some strict constructions regarding the meaning of restoration may exclude OMWM as a means of marsh restoration, others find it to be quite compatible.

## 5.8 Fresh Water Wetlands

### 5.8.1 Introduction

Fresh water wetlands are formed by water derived from groundwater and rainfall, and thus have no or low salt content. The boundaries between estuarine and fresh water wetlands often fluctuate and as a result transitional habitats are formed, which often retain characteristics of both systems (Mitsch and Gosselink, 2000).

The term “fresh water wetlands” refers to a set of non-saline ponds, bogs, fens, swamps, and marshes found throughout North America (Holst et al., 2003). These areas are identified by hydric soils saturated for a sufficient time during the growing season to develop anaerobic conditions in the soil’s upper reaches (Metzler and Tiner, 1992). The NWI defines three classes of fresh water wetlands:

- riverine: habitats associated with rivers and streams
- lacustrine: wetlands associated with lakes and ponds
- palustrine: shallow bodies of water with minimal water flow, including swamps, marshes and bogs

Fresh water systems have unique plant and animal communities that often are adapted to changing levels of water, and, in some settings, changes in salinity (Cowardin et al., 1979).

The New York State Natural Heritage Program classifies Suffolk County in the Coastal Lowlands ecozone (Edinger et al., 2002). Coastal influences with the glacially-formed landscape of moraines and outwash combine to create a diverse mosaic and include rare wetland habitats with high levels of biodiversity (Stewart and Springer-Rushia, 1998).

The formation, persistence, and size of fresh water wetlands result from hydrologic processes controlling the movement of water through the system (Carter, 1996), including, in some cases, tidal effects. Wetlands are generally defined by the presence of characteristic plant types, and, in some cases, by hydric soils (NYSDEC, 2004a). Hydric soils are soils saturated, ponded, or flooded for a sufficient time during the growing season to develop anaerobic conditions in the upper part of the soil, so that soil quality is affected by the particular chemistry that results from a lack of oxygen (Metzler and Tiner, 1992).

Differences in wetlands can result from underlying soil types, which is generally a function of geology, topography, and climate. Differences can also be attributed to the movement of water throughout wetlands, water quality, and the impacts of human disturbances. Major components of the hydrological cycle include precipitation, surface water flow, groundwater flow, and evapotranspiration. Wetlands depend exclusively on either precipitation or groundwater flow for sustaining hydric soils. In general terms, and considered over longer time spans, inputs of water are counterbalanced by losses to surface water flow and evapotranspiration for these systems (Carter, 1996).

Unsurprisingly, plant and animal species found within freshwater wetlands are closely linked to hydrology and soil characteristics. Wetland plants have adapted to thrive in conditions that most upland plants are unable to survive, overcoming anaerobic soil conditions by, for example, oxygenating saturated root zones from the air above (Holst, 1996).

A variety of plant types have evolved to varying levels of moisture found within freshwater wetlands. Wetland plant species found exclusively in the saturated soil conditions are known collectively as obligate wetland hydrophytes. In contrast, plants that grow in saturated soils, but may also be found outside wetlands, are described as facultative wetland species. Indicative plant species of freshwater wetlands include trees, shrubs, persistent emergents, and emergent mosses or lichens, among others (Mitsch and Gosselink, 2000).

Wetlands are some of the most biologically productive ecosystems and a variety of animal species live and feed within these areas (USEPA, 2001). The abundance of vegetation and shallow water makes this habitat ideal for fish and wildlife. Many species utilize fresh water habitats for protection and refuge, while others seek out wetlands for breeding, nesting, and feeding grounds (NYSDEC, 2004b). These areas are known for supporting diverse assemblages of water fowl, fish and shellfish, reptiles, and amphibians, especially.

Fresh water wetlands provide numerous beneficial qualities for the surrounding ecology, and for people. Typically, fresh water wetland functions include:

- water quality improvement

Microorganisms in wetland soils break down and use nutrients, significantly reducing the levels of natural and human-related inputs to aquatic systems (NYSDEC, 2004b). Fresh water wetland vegetation similarly filter nutrients incoming water (USEPA, 2001). Wetland plants may preferentially take up particular contaminants, and store them, thus removing the contaminants from the aquatic or benthic systems (when such practices are encouraged, this is often called "phytoremediation") (Mitsch and Gosselink, 2000).

- flood water storage

During floods, wetlands can incorporate excess water, slowing its movement through the hydrological system (NYSDEC, 2004b). The ability of wetlands to store flood waters reduces property damage and loss of life (USEPA, 2001), and has important ecological consequences, hydrologically by serving as a flow buffering system, and structurally by deterring downstream erosion (NYSDEC, 2004b).

- fish and wildlife habitat

Abundant vegetation and shallow waters provide diverse habitat for fish and wildlife to breed, nest, and feed (NYSDEC, 2004b). Juvenile estuarine fish are able to find shelter and food in tidal fresh water wetlands while shellfish and crustaceans use these same areas during their life cycles. Migratory bird species often find refuge in fresh water wetlands during their annual journeys.

- Aesthetics

Long scorned as useless and sources of disease, the undeveloped nature of fresh water systems has become prized, in many ways precisely because of the absence of human elements. Aesthetic judgements are not constants, nor will everyone reach similar conclusions, but the modern view of fresh water wetlands systems seems to be almost entirely favorable.

- biological productivity.

Fresh water wetland systems, overall, are accounted among the most productive ecosystems in the world (USEPA, 2001). Particular kinds of wetlands may not be especially productive, but constant (or greater) availability of water and general nutrient enrichment often means these areas have enhanced productivity compared to their surrounding ecotones, and some fresh water systems generally are extremely productive (Mitsch and Gosselink, 2000).

Not every wetlands have provides each service, however.

In addition to the environmental functions of wetlands, economic values include support for recreation and tourism including hunting, fishing, bird watching, and photography. The sum value of "ecotourism" to the US economy may exceed $60 billion annually (USEPA, 2001).

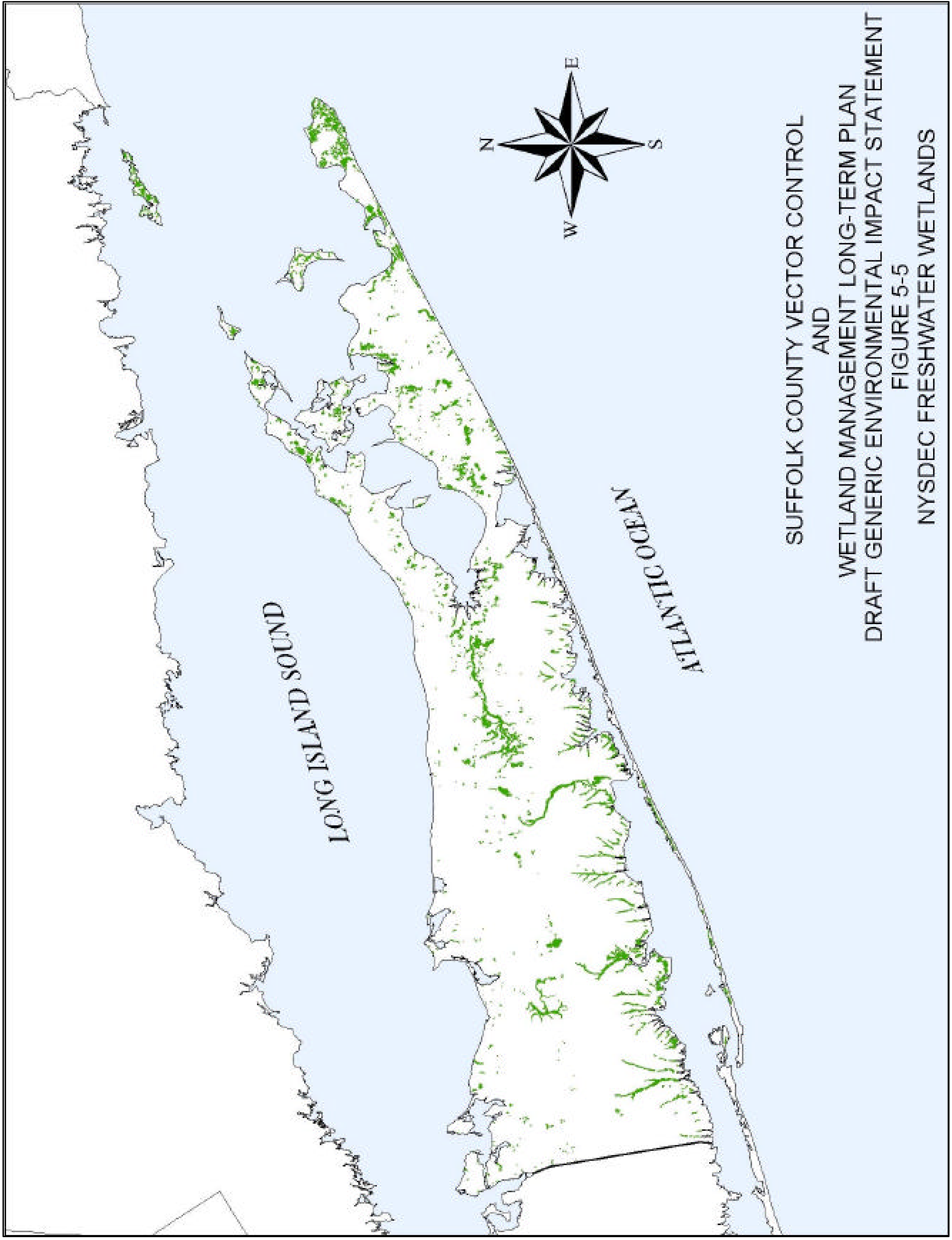
Inventories of fresh water wetlands are closely monitored by state and local agencies to help implement "no net loss" management policies. In New York State, it was estimated in the mid-1990s that 2.4 million acres of wetlands remained (NYSDEC, 2004c), with 21,000 acres in the Coastal Lowlands ecozone.

Table 5-5. Coastal Lowlands Ecozone Cover Types

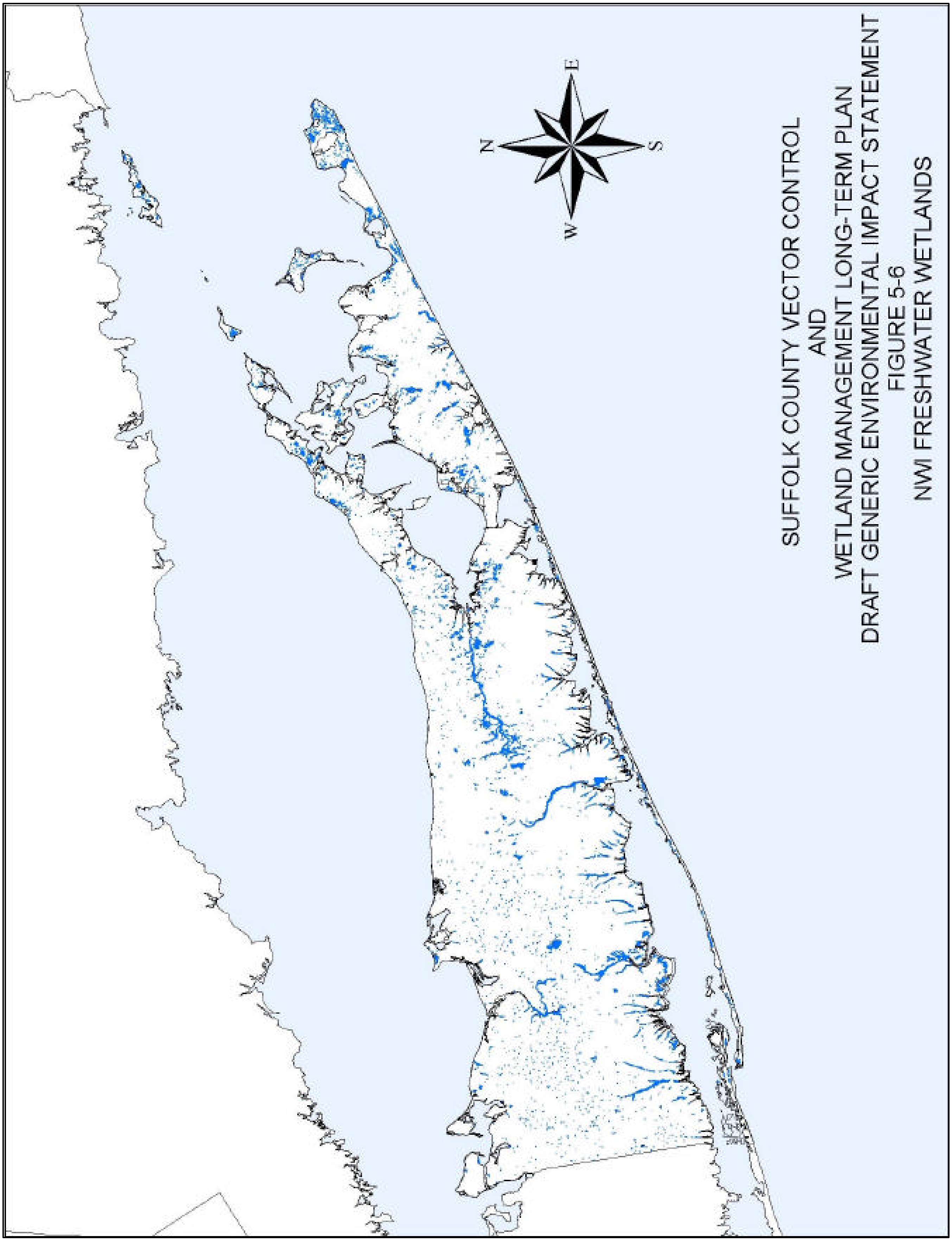
| Cover Type | Percent (21,000 acres total) |
|---|---|
| Forested | 65 |
| Open Water | 23 |
| Emergent | 8 |
| Shrub/Scrub | 3 |

In New York State, the FWA, TWA, and SEQRA represent the major regulations affecting fresh water wetlands (see Section 2). The Freshwater Wetlands Act, Article 24 of the Environmental Conservation Law, provides NYSDEC with the authority to regulate fresh water wetlands in the state (NYSDEC, 2004d). The FWA protects wetlands larger than 12.4 acres in size by implementing a series of monitoring and permitting programs. Within the monitoring program, NYSDEC is required to keep updated maps of all fresh water wetlands in the State and notify landowners of existing or emerging wetlands on their property. The permit programs examine any activities that have potential to significantly alter existing ecosystems.

Freshwater wetlands that are smaller than 12.4 acres in size are administered under 6NYCRR Part 644. The regulation states that wetlands of less than 12.4 acres in size may be registered on the NYSDEC wetland maps if they are of unusual local importance (Browne et al., 1995). On Long Island, significant fresh water wetlands smaller than 12.4 acres are identified by county, town, and local municipalities for inclusion in the New York State register of fresh water wetlands (J. Dietrich, Town of Huntington Department of Maritime Services, personal communication, 2004). Long Islanders have been fairly diligent in identifying such sites; many wetlands smaller than 12.4 aces are mapped by NYSDEC. Nonetheless, it is also clear that the NWI mapping of fresh water wetlands captures a great many more wetland sites than does the NYSDEC mapping. Figure 5-5 shows the NYSDEC mapping (which sums to 18,084 acres). The NWI mapping (Figure 5-6) clearly includes a great many more sites than does the NYSDEC mapping. However, the NWI mapping only sums to 14,172 acres (less than the NYSDEC fresh water acreage). A comparison by CA seems to indicate that NYSDEC is more expansive in its definition of wetlands along stream corridors, primarily, and this difference is sufficient to account for approximately 30 percent more acres than the NWI mapping encompasses (please note CA attempted to account for NWI classifications of tidal wetlands, even if fresh, under estuarine categories).



SUFFOLK COUNTY VECTOR CONTROL
AND
WETLAND MANAGEMENT LONG-TERM PLAN
DRAFT GENERIC ENVIRONMENTAL IMPACT STATEMENT
FIGURE 5-5
NYSDEC FRESHWATER WETLANDS



SUFFOLK COUNTY VECTOR CONTROL
AND
WETLAND MANAGEMENT LONG-TERM PLAN
DRAFT GENERIC ENVIRONMENTAL IMPACT STATEMENT
FIGURE 5-6
NWI FRESHWATER WETLANDS

### 5.8.2 Suffolk County Fresh Water Wetlands Ecological Communities

Different ecological communities are found in different fresh water wetlands on Long Island. Factors affecting the communities found in certain areas include precipitation, groundwater inflows and outflows, and tidal effects, and annual and seasonal variations in these hydrological elements also have further effects (Stewart and Springer-Rushia, 1998). One means of classifying wetlands is to consider their ecological communities; this classification necessarily includes physical attributes since the physical differences between wetland settings influence the ecology of these sites.

Generally, there are five broad categories of wetlands:

- marine
- estuarine
- riverine
- lacustrine
- palustrine.

Marine and estuarine wetlands are salt water communities. As classified by the New York State Natural Heritage Program, fresh water tidal marshes are also considered to be estuarine, due to inherent connections to deep water tidal habitats and adjacent tidal wetlands (Edinger et al., 2002). However, as they were not discussed under salt marshes above, they will be included as fresh water wetlands for this discussion.

The Natural Heritage Program has identified certain wetlands in Suffolk County as “reference” wetlands. These are sites that are of high enough quality so that they can serve as wetlands reference standards, despite the Natural Heritage Program finding that all wetlands on Long Island are impacted to some degree or another (MacDonald and Edinger, 2000). Although reference wetlands were not identified for all ecosystem types found in Suffolk County, those that were will be used in the discussion below.

The tables in this section provide lists of some significant species for each specific wetland. Because wetlands are often recognized by specific plants or plant types, these lists of individual species can be important elements for understanding the particular system being considered.

#### 5.8.2.1 Tidal Ecosystems

Fresh water wetlands that are tidal are almost exclusively found at the mouth of or along tributaries to river systems, near an estuary so that tidal influences are still experienced. Salinities are generally less than 0.5 ppt and they are normally less than six feet deep. Fresh water tidal marshes can be divided into two sub-systems:

- low elevation, broad leaf emergent zone
- higher elevation, graminoid zone.

Indicative species of this system include:

- spatterdock
- pickerel-weed
- narrowleaf cattail
- marsh wren
- red-winged blackbird

(Edinger et al., 2002)

Fresh water tidal marshes can be found near the mouths of tidal rivers in Long Island. Major fresh water systems include:

- Carmans River (reference site)
- Nissequogue River (reference site)
- Arshamonoque
- Napeague
- Crab Meadow
- Hubbards Creek
- Gardiner County Park

(MacDonald and Edinger, 2000)

These marshes are not as well developed and are relatively degraded to those found on the Hudson River. However, they have much tighter ecological connections to salt marshes than the Hudson River marshes do. Invasive *Phragmites* is an extensive problem that threatens the habitat as a whole (MacDonald and Edinger, 2000).

The 215 acre, tidal fresh water portion of the Carmans River extends south of Montauk Highway to Squassax Landing. *Phragmites* covers approximately 60 percent of the marsh. Mosquitoes were noted as a characteristic fauna. There were no rare, threatened, or endangered species noted to be in the habitat (MacDonald and Edinger, 2000).

There are 48 acres of tidal marsh along the Nissequogue River. The marsh is zonated, due to greater salinity impacts due to the higher tidal range of the North Shore. At the north part of the marsh (more saline), the plant coverage was dominated by *Scirpus robustus* and *Zizania aquatica*. In the southern stretches, dominant herbs were *Typha augustifolia*, *Scirpus novae-angliae,* and *Z. aquatica*. *Phragmites* was noted to be present, but not quantified. No species of special concern were noted (MacDonald and Edinger, 2000).

Table 5-6. Fresh Water Tidal Marsh Characteristic Species

| **Characteristic Plants** | **Characteristic Animals** |
|---|---|
| *Low elevation, broad leaf emergent zone:* spatterdock, pickerel-weed, arrowleaf, fowl mannagrass, narrow leaf arrowheads, mud-plantain.<br>*Higher, graminoid zone:* narrowleaf cattail, river bulrush, bur-reed, wild rice, blue flag. | Marsh wren, red-winged blackbird, swamp sparrow, Virginia rail, song sparrow, yellow warbler, least bittern, American goldfinch, willow flycatcher, common yellowthroat. |

#### 5.8.2.2 Riverine Ecosystems

The NWI defines riverine wetlands as the wetlands and deeper water habitats contained within a channel, except those that contain persistent emergent vegetation, trees, shrubs, or having more than 0.5 ppt salinity (Cowardin et al., 1979). Community types are generally classified by water flow rates, substrate composition, and faunal and vegetative species present. Plants found in riverine fresh water wetlands include:

- emergent and submergent bryophytes
- hydrophytic vascular plants
- submergent vegetation such as pondweeds and naiads

Common animals include:

- American eel
- eastern banded killifish
- Asiatic clams

(Holst et al., 2003)

Riverine fresh water wetlands are found along the streams and rivers of Suffolk County. Two types of riverine wetlands are intermittent or ephemeral streams, and coastal plain streams (Edinger et al., 2002). The Natural Heritage Program (MacDonald and Edinger, 2000) has not identified any reference members of this ecological community on Long Island, but identified the upper reaches of the Carmans and Peconic River as examples of intermittent streams, and the main body of those rivers as examples of coastal plain streams (Edinger et al., 2002).

Intermittent streams do not have permanent flows, and water may remain in the streambed for fairly long times as ponded, isolated pools. Fauna is limited to those species that do not require permanent running water (Edinger et al., 2002).

There are also numerous, generally unbranched streams, whose headwater locations depend on the water table height, flowing south from the Ronkonkoma moraine. Upper reaches of these streams would be intermittent streams, and, where flows have not been dammed, the lower reaches would be coastal plain streams.

It should be noted that the Peconic River is classified as a "warm water" river, meaning it cannot support trout (Cashin Associates, 2004c). The Carmans River, although also a groundwater-fed stream, will support trout (Cashin Associates, 2002).

Table 5-7. Riverine Wetlands Characteristic Species

| **Wetland Type** | **Characteristic Plants** | **Characteristic Animals** |
|---|---|---|
| **Intermittent Stream** | Emergent and submergent bryophytes *(Bryhnia novae-angliae, Bryum psuedotriquertrum).* Hyrdophytic vascular plants: water-carpet, pennywort. | Green frog, northern two-lined salamander, water striders, water boatman, caddisflies, mayflies, stoneflies, midges, blackflies, crayfish. |
| **Coastal Plain Stream** | Submergent vegetation: pondweeds, naiads, waterweeds, stonewort, bladderwort, duckweed, Tuckerman's quillwort, white water-crowfoot, watercress. | American eel, redfin pickerel, eastern banded killifish, pumpkinseed, banded sunfish, swamp darter, Asiatic clam, large mouth bass, black crappie, yellow perch, chain pickerel, muskrat, mink. |

### 5.8.2.3 Lacustrine Ecosystems

Suffolk County lacustrine fresh water wetlands, as defined by the Natural Heritage Program, include coastal plain ponds and eutrophic ponds. However, it seemed proper to include vernal ponds and Pine Barrens vernal pools in this category, although they are not permanent bodies of water (as many coastal plain ponds are not permanent, either).

Lacustrine wetlands are defined as the wetlands and deeper water habitats situated in a topographical depression or dammed river channel, lacking trees, shrubs, persistent emergent vegetation, and emergent mosses (Holst et al., 2003). Lakes and ponds falling under this category have low directional flow (Stewart and Springer-Rushia, 1998). Characteristic life found in lacustrine freshwater wetlands include:

- white water-lily
- bladderwort, pondweed
- peat moss
- algae
- pickerel
- sunfish
- tiger salamander
- muskrat

(Holst et al, 2003)

Lacustrine freshwater wetlands can be found along streams and rivers (often formed by dams), where groundwater is perched along the moraines, or where the water table has filled kettle holes or other isolated depressions throughout the County (Edinger et al., 2002).

Coastal plain ponds are described as the permanently and semi-permanently flooded portions of waterbodies that occur in kettleholes and shallow depressions in the outwash plain (Edinger et al., 2002). 57 coastal plain ponds have been identified by the Natural Heritage Program. The western-most example is in Coram, and the eastern-most in the Montauk Peninsula. They tend to be found in three general areas:

- the north-south trending kettle valleys that form the headwater region of the Peconic River
- the northern slopes of the Ronkonkoma moraine, especially near Riverhead

- the Long Pond complex south of Sag Harbor

(MacDonald and Edinger, 2000)

These systems are characterized by disturbances. The primary disturbance is water levels, which are linked to water table heights and rainfall. Ponds in hillier terrain appear to be affected more by groundwater changes, while those in more level settings appear to be affected more by rainfall trends (although water table levels and rainfall trends are also linked). Typically, two to three year cycles of decreasing water levels of increasing water levels tend to result. Fires, and, if located near to the shore, salt water inputs from exceptional storms, are also processes that can affect these systems (MacDonald and Edinger, 2000). Crooked Pond, Scoy Pond, Kents Pond, Weeks Pond, and the ponds found in Robert Cushman Murphy Park are all examples of coastal plain ponds.

Coastal plain pond shores are very diverse communities and have been well characterized. Because of the trends in water levels, several different vegetation communities have been identified as characteristic:

- *Eleocharis-Eriocaulon* aquatic semi-permanently flooded vegetation alliance
- *Carex striata* seasonally flooded alliance
- *Rhynchospora spp-Rhexia virginica* seasonally flooded herbaceous alliance

These communities are defined by the extent of any water table variation, position along the shore, and specific vegetation composition in any one pond. In any single growing season, a pond may display more than one association, and the associations might better be considered as zones or guilds generated by the hydrologic fluctuations. The three major alliances are expressed through the following particular vegetation associations:

- *Juncus militaris* herbaceous vegetation
- *Nymphaea odorata-Eleocharis robinsi* herbaceous vegetation
- *Rhexia virginica-Panicum verrucosum* herbaceous vegetation
- *Eleocharis obtuse-Eleocharis flavescens-Eriocaulon aquaticum* herbaceous vegetation
- *Calex striata var. brevis* herbaceous vegetation

- *Lysimachia terrestris-Dulichium arundinaceum* herbaceous vegetation

The latter two are not as common (MacDonald and Edinger, 2000).

The reference sites (see just below) all are permanent waterbodies. This is not characteristic of coastal plain ponds in general. Smaller ponds often draw down completely at times. Species such as fish that are dependent on aquatic habitat cannot be sustained. If isolated, these smaller ponds will entirely lack fish. If connected, they may lack fish only at lowest water levels when refilling, as reestablishing a connection to larger ponds will allow fish to recolonize. Ponds that lack fish are much more likely to support amphibian populations, especially tiger salamanders, due to a lack of predation. Nearly 80 such small ponds are found near the Peconic River headwaters including Woodchoppers Pond, Horn Pond, and Round Pond Peconic). There is also a cluster of ponds near Long Pond and Crooked Pond (including Whalers Drive Pond, Powerline Pond, Deer Drink, Scuttlehole Road Ponds, Pond North of Black Pond, and Ponds East and Southeast of Slate Pond) (MacDonald and Edinger, 2000).

Five reference locations for coastal plain ponds were selected by the Natural Heritage Program:

- Peasys Pond (Riverhead and Brookhaven Towns)

Peasys Pond is large (nine acres) for a coastal plain pond, and has developed vegetation on sandy and mucky shorelines as well as a central peat island. Its vegetation tends to be strongly delineated. It has been subject to frequent fires which cause variability in surrounding upland vegetation. Rare species found at Peasys Pond include:

  - *Sagittaria teres*
  - *Enallagma recurvatum*
  - *Rhynchospora nitens*
  - *R. scipoides*
  - *Utricularia striata*
  - *U. junccea*
  - *Iris prismatica*
  - *Proserpinaca pectinata*

  - *Ludwigia sphaerocarpa*
  - *Enneaanthus obseus*
  - *Coreopsis rosea*
  - *Lobelia nuttallii*

- House Pond (Southampton)

House Pond is also large (five acres), and contains a variable shore slope and organic matter zones, and its microtopography appears to affect groundwater discharge. Its basin also contains shallow peat mats, an Atlantic white cedar swamp, and a coastal plain poor fen. The pond itself supports floating peat over deeper portions of the pond, and its diverse vegetation has shown responses to fluctuating water levels. The Natural Heritage Program classified its hydrological and fire "regimes" as "intact." Rare species found in House Pond include:

  - *Enallagma recurvatum*
  - *Rhynchospora nitens*
  - *R. scipoides*
  - *Utricularia striata*
  - *U. junccea*
  - *Proserpinaca pectinata*

- Division Pond (Southampton)

Division Pond is also large (six acres), and it has a strong groundwater discharge. The pond itself supports floating peat over deeper portions of the pond, and has well developed organic deposits. Its diverse vegetation has shown responses to fluctuating water levels. The Natural Heritage Program classified its hydrological and fire "regimes" as "intact." Rare species found in Division Pond include:

  - *Mitoura hessel*
  - *Psectraglaea carnosa*
  - *Enallagma recurvatum*

  - *Rhynchospora scipoides*
  - *Utricularia striata*
  - *Lobelia nuttallii*
  - *Euxoa violaris*
- Long Pond Sag Harbor (Southampton)

Long Pond is very large (60 acres) and contains a wide, level shoreline. It has deeper areas in the pond, and supports a coastal plain poor fen at its southern end. Vegetation diversity is very high, partly due to the large draw down areas. Rare species at Long Pond include:

  - *Eupatorium aromaticum*
  - *Lachnanthes carolina*
  - *Hypericum adpressum*
  - *Hydrocotyle verticillata*
  - *Crassula aquatica*
  - *Planthera ciliaris*
  - *Aster concolor*
  - *Enallagma laterale*
  - *Rhynchospora inundata*
  - *R. nitens*
  - *R. scipoides*
  - *Lespedeza suevei*
  - *Eleocharis equisetoides*
  - *Ludwigia sphaerocarpa*
  - *Digitaria filiformis*
  - *Linum medium var texanum*
  - *Agalinis fasciculata*

  - *Coreopsis rosea*
  - *Trichostema setaceum*

- Crooked Pond (Southampton)

Crooked Pond, another large pond (14 acres), has a varying set of shorelines, ranging from flat and sandy to steeper and gravelly slopes. It has a complexly lobed shoreline, creating small coves that collect organic matter and increase topographical diversity. It supports faunal species such as wood duck, painted turtle, muskrat, dragonflies, and damselflies. Rare species found in Crooked Pond include:

  - *Hypericum adpressum*
  - *Amphicarpum purshii*
  - *Lachnanthes caroliana*
  - *Enallagma recurvatum*
  - *E. laterale*
  - *E. pictum*
  - *Eleocharis equisetoides*
  - *E. tuberculosa*
  - *Rhynchospora nitens*
  - *R. scipoides*
  - *Aletris farinosa*
  - *Ludwigia sphaerocarpa*
  - *Ishnura kellicotti*
  - *Polygonum hydropiperoides var. opelousanum*
  - *Agalinis fasciculata*
  - *Coreopsis rosea*
  - *Gnaphalium helleri var. micradenium*

Peasys Pond, House Pond, Long Pond and Crooked Pond are considered connected ponds because water flows to and from them. By contrast, Division Pond is considered to be unconnected as it is isolated from other waterbodies (MacDonald and Edinger, 2000).

Eutrophic ponds tend to be small, shallow, murky, nutrient rich bodies of water. The water is often green, due to primary production, and the bottom is mucky. Alkalinity levels can also be high (Edinger et al., 2002). On Long Island, they often are isolated, and predominantly groundwater fed. When surrounded by development, these ponds often become degraded. The Natural Heritage Program refers to excessively eutrophied ponds as “culturally eutrophied lakes,” and notes they may be subject to blooms of cyanobacteria and invasions by macrophytes such as Eurasian water milfoil, water chestnut, and pondweed (Edinger et al., 2002). Many artificial ponds (recharge basins with permanent water or dammed streams) become very eutrophic, either through run-off or excessive water fowl populations.

The Natural Heritage Program (MacDonald and Edinger, 2000) has not identified any reference members of this ecological community on Long Island, nor has it publicly identified representatives of the class (Edinger et al., 2002). Eutrophic ponds, although relatively ecologically depauperate in and of themselves, can be important ecological elements in suburban Suffolk County. They consist of undeveloped area, for one, and, as open water, can be a rare resource in a landscape dominated by very porous sands that do not support many surface water features.

Vernal ponds were classified by the Natural Heritage Program as palustrine because they are only intermittent or ephemeral. The description focuses on the depression that is filled with water when they are ponds. These are typically found in upland, forested areas. State-wide, vernal pools typically appear in spring, disappear in summer, and may reappear in fall (Edinger et al., 2002). However, if groundwater inputs comprise a portion of their hydrology, the model may not be completely followed on Long Island. Some vernal pools form on Long Island due to winter frost inhibiting recharge.

They tend to have a leaf litter as a substrate. Because they lack permanent waters, these ponds are rich habitats for amphibians and invertebrates since fish predation is absent. A distinction is made between obligate species that require vernal pools for life, and facultative species, which are species that will use vernal pools, but also can live in other habitats. Plants found in vernal pools tend to be hydrophytic, and tend to be comprised of a mix of facultative and obligate floating and submergent plants. Emergent plants tend not to be represented (Edinger et al., 2002).

The Natural Heritage Program (MacDonald and Edinger, 2000) has not identified any reference members of this ecological community on Long Island, nor has it publicly identified representatives of the class (Edinger et al., 2002).

Pine barrens vernal pools are groundwater fed ponds where water levels fluctuate, and which may disappear entirely during some seasons. They tend to be small. Pine barrens vernal ponds may have four rings of vegetation communities. The center may be comprised of submerged aquatic plants. The shore may support emergent plants, especially sedges. Low shrubs may surround the pond, with stunted trees on hummocks within or around the wetland. Because these ponds are too small, and are often ephemeral, they do not support fish but instead support a thriving amphibian and invertebrate community (Edinger et al., 2002). The Natural Heritage Program (MacDonald and Edinger, 2000) has not identified any reference members of this ecological community on Long Island, nor has it publicly identified representatives of the class (Edinger et al., 2002).

Table 5-8. Lacustrine Wetlands Characteristic Species

| **Wetland Type** | **Characteristic Plants** | **Characteristic Animals** |
|---|---|---|
| **Costal Plain Pond** | Aquatic vegetation: water-shield, white water-lily, bayonet-rush, spikerush, bladderworts, water milfoil, naiad, waterweed, pondweed, pipewort, brown-fruited rush, golden-pert, peat moss. | Chain pickerel, brown bullhead, banded sunfish, eastern mudminnow, tiger salamander, painted turtle, wood duck, muskrat. |
| **Coastal Plain Pond Shore** | *Upper wetland shrub thicket*: Pine Barrens shrubs, highbush blueberry bog thickets. *Upper, low herbaceous fringe*: peat moss, yellow-eyed grass, narrow leaved goldenrod. *Sandy exposed pond bottom*: beakrushes, nutrush. *Organic exposed pond bottom*: bald-rush, pipewort, gratiola. | Eastern painted turtle, muskrat, dragonflies, damselflies, chain pickerel, bluets, eastern mudminnow, tiger salamander, banded sunfish. |
| **Eutrophic Pond** | Aquatic vegetation: coontail, duckweeds, waterweed, pondweeds, water starwort, bladderworts, naiad, tapegrass, algae, white water-lily. | Warmwater fishes, odonates, leeches, phytoplankton, zooplankton, rotifers. |
| **Vernal Pool** | Manna grass, spike rush, water purslane, duckweed, water hemlock, bryophytes (*Brachytheceium rivulare, Callergion spp., Sphagnum spp*.), featherfoil | Obligate species: spotted salamander, blue-spotted salamander, Jeffersons salamander, marbled salamander, wood frog, fairy shrimp. Facultative species: four-toed salamander, red-spotted newt, spring peeper, gray tree frog, American toad, painted turtle, spotted turtle, snapping turtle, fingernail clams, snails, water scorpions, diving beetles, whirligig beetles, dobsonflies, caddisflies, dragonflies, mosquitoes, leeches. |

| | | |
|---|---|---|
| **Pine Barrens Vernal Pond** | Pondweeds, woolgrass, soft rush, tussock sedge, marsh St. John's-wort, cinnamon fern, marsh fern, Virginia chain fern, mosses, highbush blueberry, winterberry, leatherleaf, buttonbrush, black chokeberry, black huckleberry, mountain holly, meadow sweet, red maple, gray birch, pitch pine, quaking aspen. | Eastern American toad, northern spring peeper, green frog, wood frog, eastern spadefoot toad, Fowler's toad, Jefferson salamander, spotted turtle, common snapping turtle, red-winged blackbird, common yellowthroat, beetles, water striders. |

### 5.8.2.4 Palustrine Ecosystems

Palustrine fresh water wetlands found on Long Island include a variety of swamps, marshes, and bogs. Palustrine wetlands are defined as non-tidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, and lichens, in shallow waters generally no deeper than six feet (Cowardin et al., 1979). Palustrine fresh water wetlands found on Long Island include:

- coastal plain Atlantic white cedar swamps
- red maple - black gum swamps
- shrub swamps
- Pine Barrens shrub swamps
- shallow emergent marshes
- maritime freshwater interdunal swales
- coastal plain poor fens
- sea level fens
- highbush blueberry bog thickets

(Edinger et al., 2002)

Edinger et al. also describe coastal plain pond shores, vernal ponds, and pine barrens vernal ponds as palustrine wetlands, but these were discussed above.

**Swamps**

Swamps are characterized by a dense growth of tress growing in wet soil, peat or standing water (Stewart and Springer-Rushia, 1998). Water pH may range from very acidic to nearly neutral. A variety of swamps is found in Suffolk County, including:

- coastal plain Atlantic white cedar swamps
- red maple - black gum swamps
- shrub swamps

- Pine Barrens shrub swamps

(Edinger et al., 2002)

These swamps all have type-specific vegetation; some species found throughout swamps systems include:

- Atlantic white cedar
- red maple
- pitch pine
- water-willow
- swamp azalea
- cinnamon fern
- black gum (tupelo)
- common yellowthroat
- American bittern
- alder flycatcher
- white-tailed deer

(Edinger et al., 2002)

Coastal plain white cedar swamps are a conifer or mixed conifer-deciduous swamp that occurs along streams or in poorly drained depressions. Soils tend to be highly organic. Atlantic white cedar makes up 50 percent of the cover, with red maple sometimes being co-dominant. The canopy cover is expected to be at least 50 percent (Edinger et al., 2002). The Natural Heritage Program (MacDonald and Edinger, 2000) has not identified any reference members of this ecological community on Long Island. Cranberry Bog County Park was identified as being representative of the class (Edinger et al., 2002).

Red maple - black gum swamps are defined as maritime, coastal, or inland swamps formed in poorly drained depressions, often occurring in a narrow band between streams and their uplands. Red maple and black gum can be co-dominant, or black gum may be dominant. There is often a well-developed shrub layer. Hummocks and hollows tend to define the topography. Most occurrences of this ecosystem in New York State are in Suffolk County, from the Connetquot River east to Montauk Point (Edinger et al., 2002). The Natural Heritage Program (MacDonald and Edinger, 2000) has not identified any reference members of this ecological community on

Long Island. Particular sites specified by the Natural heritage Program include Sunken Forest, Fire Island, the Connetquot River watershed, and the lower Peconic River (Edinger et al., 2002).

Shrub swamps are inland wetlands dominated by tall shrubs. They tend to be found along lake or river shores, or to form transition zones between low relief settings (bogs, marshes, fens) and higher relief settings such as swamps, or the uplands. They are a diverse set of communities, and the Natural Heritage Program has not completed research to distinguish between the sub-types. They can provide important cover for birds (Edinger et al, 2002). The Natural Heritage Program (MacDonald and Edinger, 2000) has not identified any reference members of this ecological community on Long Island, nor has it publicly identified representatives of the class (Edinger et al., 2002).

Pine Barrens shrub swamps are shrub-dominated wetlands that often serve as a transition between coastal plain pond shores and surrounding uplands. They are found east of the Connetquot River, either embedded in the Ronkonkoma Moraine, or in the channel valleys that form the headwaters of the Peconic River, in pitch pine-oak barrens common to eastern Long Island, and are similar to the highbush blueberry bog thicket. It exists in dynamic tension between expansion of adjacent wetlands and impacts from fire and frost; it has some similarities to the *Vaccinium corymbosum-Spagnum spp.* community recognized nationally (MacDonald and Edinger, 2000).

Six specific examples of this ecosystem were found by the Natural Heritage Program. The Peconic Headwaters Wetlands and Sears Bellows Wetlands were identified as reference sites (MacDonald and Edinger, 2000).

The Peconic Headwaters Wetlands consists of 26 acres of narrow (two to 10 m) of small bands or thin patches creating a transition from basins or streams to surrounding uplands. The contiguous, net-like extent of this example is the result of numerous depressions intercepting the water table. Tree canopy ranges from six to 12 m in height, and covers 10 to 30 percent of the landscape (much less following recent fire), and can include fire-killed snags. A tall shrub layer (two to four m tall) has 25 to 60 percent coverage, and is reduced to two m in height following fire. The short shrub layer is highly variable, and its coverage ranges from 25 to 90 percent (greater following fire). Soils are shallow and can be inundated as much as 20 cm deep in high rainfall years. Its coverage varies over time due to hydrological changes. *Gaylussacia dumosa* is a rare plant found in this wetland (MacDonald and Edinger, 2000).

The Sears Bellows Wetlands shrub swamp consists of 21 acres found in a narrow (one to four m) margin surrounding various wetlands. A 10 m tree canopy covers as much as 42 percent of the system (but as little as 10 percent following fires). The tall shrub layer (2.5 to three me tall) is diverse, and was described as having 47 percent cover. The short shrub layer covered one to 30 percent, and there was a vine layer at this site. Windthrow and flooding (with salt water) during coastal storms may be important factors at this site. *Gaylussacia dumosa* and *Camaecyparis thyoidesis* are rare plants found in this wetland (MacDonald and Edinger, 2000).

**Marshes**

Marshes are dominated by grasses, sedges, or rushes in addition to several species of herbaceous plants. Shrubs may also be present but trees are often not found in this ecosystem. As a result marshes are characterized as relatively open environments. Marshes may be further subdivided into: rich fens, which contain an abundance of nutrients; or, poor fens, where nutrients are scarce. In Suffolk County, marshes include:

- shallow emergent marshes
- maritime fresh water interdunal swales
- coastal plain poor fens
- sea level fens

Indicative life in these ecosystems are:

- herbaceous plants
- rushes
- sedges
- toads
- frogs
- great blue heron
- spotted turtle

Shallow emergent marshes are emergent communities that occur on mineral soils or mucks (rather than true peats). They have permanently saturated soils, and are seasonally flooded. Water levels range up to 1 m, but the substrate is exposed for some time during a typical year.

They tend to occur in lake basins, or along streams. They may intergrade into shrub swamps or be part of an overall wetland mosaic (Edinger et al., 2002). The Natural Heritage Program (MacDonald and Edinger, 2000) has not identified any reference members of this ecological community on Long Island, nor has it publicly identified representatives of the class (Edinger et al., 2002).

Maritime fresh water interdunal swales occur in low areas between dunes on the coast, in low areas or swales at blowouts that lower the soil to the water table, or through seaward extension of a dune field. They are fed by groundwater, and so water levels fluctuate according to the water table height. Sedges and herbs are the dominant vegetation, although low shrubs may also be present. They tend to be small with low species diversity, and the species found at one example of such a wetland may be markedly different from those found at another (Edinger et al., 2002). The Natural Heritage Program (MacDonald and Edinger, 2000) has not identified any reference members of this ecological community on Long Island. Examples include the Napeague Dunes, the Atlantic Double Dunes, and the Walking Dunes (Edinger et al., 2002).

Coastal plain poor fens are weakly minerotrphic peats, primarily *Sphagnum*, with scattered sedges, shrubs, and stunted trees (Atlantic white cedar or red maple). They are formed by low pH, mineralized water in fills associated with coastal plain ponds, or in reverting agricultural landscape, especially cranberry bogs or older impoundments. The fens seem to be formed where multiple hydrological inputs intersect (groundwater, small streams, even fresh water tides), and organic matter deposition exceeds decomposition to form the peat. Three unusual examples appear to exist where groundwater discharges at the margin of small tidal fresh water creeks. All 11 examples occur east of Apple Neck Wetlands in Islip (MacDonald and Edinger, 2000).

Although Cranberry Bog and Fresh Pond were considered, the only reference wetland selected by the Natural Heritage Program was Jones Pond (Riverhead). This 10 acre site, formed in five distinct north-south trending patches, is located in the kettle valleys associated with the headwaters of the Peconic River. It consists of a matrix of low shrubs with sedge patches on a quaking peat mat. Hydrology at this site is variable due to changes in groundwater discharge, pond surfaces, and stream inputs, and fire may affect the community. A small dam at the southern end of the system may have influenced the creation of this community. Rare species include:

- *Utricularia striata*
- *Gaylussacia dumosa*
- *Arethusa bulbosa*
- *Ludwiga sphaerocarpa*
- *Phynchospora scirpoides*

Sea level fens are small-patch sedge dominated fen communities found at the upper edge of salt marshes. They are dominated by acidic, oligitrophic fresh water seepage, and receive salt water inputs only on unusually high tides. They are herb dominated, with high species diversity, and only infrequent tree or shrub coverage. In the vicinity of the Peconic Bay, it is found in conjunction with morainal features such as outwash channels or outwash fans. The largest site in Suffolk County is in Heckscher Park, however, on a large outwash fan. There is strong groundwater discharge into these fens. Nine examples were found, although an example on Fire Island was thought to be a questionable identification (MacDonald and Edinger, 2000).

Northwest Creek contained a 27 acre reference site. The patches of fen are interspersed with red maple-black gum swamp, and bordered seaward by high marsh (salt marsh). A good upland buffer exists, making this a relatively protected site. Banding due to differences in tidal impacts has occurred. Dense bands of *Eleocharis rostellata*, *Scirpus pungens*, and *Cladium mariscoides* are found. Rare species include:

- *Sabatia campanulata*
- *Iris prismatica*
- *Lilaeopsis chinensis*
- *Fimbristylis castanea*
- *F. caroliniana*
- *Carex hormathodes*

(MacDonald and Edinger, 2000)

Heckscher State Park has a 25 acre fen. The fen was formerly the site of extensive farming, and is surrounded by a causeway, which disrupts its hydrology, despite the presence of a three m.-wide culvert and channel under the roadway. Vegetation is diverse, with bands of *Scirpus pungens* and *Cladium mariscoides*, and large populations of *Andropogon glomeratus* and *Iris prismatica*. Rare plants include:

- *Bartonia paniculata*
- *Iris prismatica*

(MacDonald and Edinger, 2000)

**Bogs**

Bogs are highly acidic wetlands where peat accumulates due to the decay of plant material. These habitats are often the peat is covered by a layer of sphagnum mosses. Due to a combination of low nutrients, high acidity, and low levels of dissolved oxygen, an unusual variety of herbaceous plants occupy this niche (Stewart and Springer-Rushia, 1998). An example of a bog in the Coastal Lowlands ecozone would be the highbush blueberry bog thicket. Bogs tend not to be as open as marshes due to a greater presence of shrubs. Indicative species of this ecosystem would be:

- highbush blueberry
- cinnamon fern
- swamp azalea
- marsh St. John's-wort
- swamp sparrow
- meadow jumping mice
- southern red-backed vole
- green frog

The highbush blueberry bog is a peatland dominated by tall deciduous shrubs as well as peat mosses. Highbush blueberry is, not surprisingly, the dominant shrub. Long Island examples of this ecosystem include numerous coastal species indicator species, such as pitch pine and Atlantic white cedars. Nine locations of this community were described, all of them east of Brookhaven Town (MacDonald and Edinger, 2000).

Although Mashomack was considered as a reference site, Sears Bellows wetlands was selected along with Hither Hills North. Sears Bellows includes 73 acres, and is comprised of the highly acidic (pH of 4.0 to 4.2) elements of the matrix of wetlands, marked by acid-loving plants such as *Chamaedaphne calyculata* and *Gaylussacia dumosa*. Coarse debris in the peat suggests that the history of this site has been variable. Fire is frequent, and frost appears to be important, as die back in the bog may occur several weeks before other nearby plants appear to be affected. Rare plants at this site include *Gaylussacia dumosa* and *Chamaecyparis thyoides* (MacDonald and Edinger, 2000).

Hither Hills North is a 46 acre site in two pond basins along the moraine ands shoreline, and being overlapped by migrating parabolic dunes. It has a much higher pH than other sites (5.8 standard units), and also contains species such as *Myrica gale* and *Rosa palustris* that may indicate salt spray inputs, especially during coastal stor2ms. One basin suffers from extensive *Phragmites* invasion. Rare species include *Propserpinaca pectinata* and *Utricularia striata* (MacDonald and Edinger, 2000).

Table 5-9. Palustrine Wetlands Characteristic Species

| Wetland Type | Characteristic Plants | Characteristic Animals |
|---|---|---|
| **Coastal Plain Atlantic White Cedar Swamp** | Atlantic white cedar, red maple, black gum, pitch pine, sweet pepperbush, highbush blueberry, swamp azalea, inkberry, dangleberry, black huckleberry, sheep laurel, black chokeberry, cinnamon fern, marsh fern, wintergreen, sundew, pitcher plant, sundews, bladderworts, mosses. | Hessel's hairstreak moth. |
| **Red Maple-Black Gum Swamp** | Red maple, black gum, pitch pine, sweet pepperbush, highbush blueberry, swamp azalea, fetterbush, dangleberry, inkberry, greenbrier, sawbrier, Virginia creeper, poison ivy, cinnamon fern, skunk cabbage, netted chain fern, mosses. | Vireos, warblers, thrushes, white-tailed deer. |
| **Shrub Swamp** | Alder, red osier dogwood, silky dogwood, water-willows, buttonbush, meadow sweet shrub, steeple-bush shrub, swamp azalea, highbush blueberry, sweet pepperbush, inkberry, leatherleaf. | Common yellowthroat, American bittern, alder flycatcher, willow flycatcher, Lincoln's sparrow. |
| **Pine Barrens Shrub Swamp** | Highbush blueberry, inkberry, male-berry, fetterbush, sweet pepper-bush, staggerbush, red chokeberry, bayberry, swamp azalea, leatherleaf, dwarf huckleberry, sheep laurel, large cranberry, dangleberry, Virginia chain fern, cinnamon fern, marsh fern, tussock sedge. | Information Needed |
| **Shallow Emergent Fresh Water Marsh** | Herbaceous plants: bluejoint grass, cattails, sedges, marsh fern, manna grasses, spikerushes, bulrushes, three-way sedge, goldenrods, loosestrifes. Also blue flag iris, sensitive fern, common skullcap, rough alder, water willow, shrubby dogwoods. | Eastern American toad, northern spring peeper, green frog, northern redback salamander, red-winged blackbird, marsh wren, common yellowthroat. |
| **Maritime Fresh Water Interdunal Swales** | Twig-rush, cyperus, marsh rush, round-leaf sundew, threadleaf sundew, cranberry, stiff yellow flax, bladderwort, slender yellow-eyed grass, bayberry, sweet gale, highbush blueberry. | Information Needed |
| **Coastal Plain Poor Fen** | Mosses of *Sphagnum* species; shrubs including hardhack, leatherleaf, large cranberry, water willow, sweet gale, and dwarf huckleberry; herbs including twig-rush, sedges, beakrushes, rushes, cottongrass, sundews, marsh St. John's-wort, bladderworts, swamp loosestrife. | Spotted turtle, red backed salamander, common snipe, great blue heron, green frog, bull frog, painted turtle. |
| **Sea Level Fen** | Spikerush, twig-rush, three-square, sedge, slender blue flag, Canada rush, white beakrush, Canadian burnet, wild germander, poison ivy, large cranberry, red cedar, pitch pine, bayberry, groundsel-tree, salt-marsh elder, reedgrass. | Information Needed |
| **Highbush Blueberry Bog Thicket** | Highbush blueberry, winterberry, cinnamon fern, marsh fern, swamp azalea, ed chokeberry, maleberry, fetterbush, sweet pepperbush, water willow, buttonbush, marsh St. Johns-wort, sedges, Virginia chain fern, pitch pine, Atlantic white cedar, peat mosses. | Common yellowthroat, swamp sparrow, song sparrow, meadow jumping mouse, masked shrew, southern red-backed vole, green frog. |

### 5.8.3 Generalized Distribution of Fresh Water Wetlands in Suffolk County

The north shore of Suffolk County is represented by an area that extends from the Nassau – Suffolk County border west to the Peconic River – Pine Barrens area. It is largely defined by the morainal systems. These moraines that define the hilly topography of the north shore also resulted in kettlehole ponds, formed when large pieces of ice were trapped below layers of sediment and subsequently melted leaving depressions in the earth's surface. The area is bounded by the Long Island Sound to the north and thus any streams in this area eventually combine with the salt water of the Sound. Fresh water wetlands found on the north shore include:

- fresh water tidal marsh
- intermittent stream
- coastal plain kettlehole pond
- eutrophic pond
- shallow emergent marsh
- shrub swamp
- highbush blueberry bog thicket
- red maple – black gum swamp

The Nissequogue River is the north shore's only major river, with its headwaters originating near Hauppauge. Hauppauge Springs and other groundwater fed bodies of water can be found at the southernmost reaches of the river and fresh water marshes and swamps can often be found on their fringes (Native America, 2004). In the near vicinity of the river are a variety of ponds. A 15-acre pond is found adjacent to the former Kings Park Psychiatric Center. Caleb Smith State Park., found along the river, is home to Willow Pond, Webster Pond, Mill Pond, and Millers Pond, all fresh water habitats.

Other minor streams often flow down the steeply-sloped valleys into the north-south harbors, including streams at Cold Spring Harbor, Huntington Harbor, Centerport Harbor, Northport Harbor, and Port Jefferson Harbor. Several flow into Stony Brook Harbor. Development has often resulted in the sewering or other channeling of these and other now lost streams. Many of these watercourses may have been intermittent, flowing only under run-off conditions or when the groundwater table is elevated.

Lake Ronkonkoma is one of the largest kettlehole ponds in Suffolk County, with its depths reaching into the water table and tapping into a constant source of available fresh water. Spectacle Pond is located near Lake Ronkonkoma as are other small kettleholes ponds such as Gould Pond. Other kettlehole lakes can be found throughout the north shore. Twin Ponds Nature Park near Route 25A in Centerport is host to two fresh water ponds and streams and adjacent tidal fresh water marshes. Route 25, from the Nassau-Suffolk border east to the Greenlawn area, is often bordered by small perched ponds in the folds and hollows of the hilly terrain. Other isolated ponds pock the landscape

The south shore outwash plain community extends from the Nassau County border east to the Carmans River and is bounded by the moraine to the north. This region’s topography and geology is a product of meltwaters that carried sediments from the terminal moraines to the north to the bay and ocean to the south. As result the area is typified by several deltas that have subsequently formed tidal rivers, streams and marshes throughout the region. The generally flat relief does have a series of fluves carved into it – relict river valleys from the glacial melting, or floodings of glacial lakes dammed behind the moraines. In addition, the barrier islands to the south represent unique habitats that fall between the Great South Bay to the north and the Atlantic Ocean to the south. Fresh water wetland communities found in the region include:

- fresh water tidal marsh
- coastal plain stream
- intermittent stream
- coastal plain pond
- shallow emergent fresh water marsh
- shrub swamp
- maritime fresh water interdunal swales
- red maple – black gum swamp

- vernal pool
- coastal plain Atlantic white cedar swamp
- pitch pine – blueberry peat swamp

Groundwater-fed streams are common on the south shore outwash plain and include (Dowhan et al., 1997a):

- Orowoc Creek
- Champlin Creek
- Connetquot River
- Swan River
- Beaverdam Creek

The Connetquot River is part of Connetquot River State Park, a 4,500 acre undeveloped coastal watershed system that is fed by several natural cold water streams to the north. A tidal fresh water marsh can be found along the Connetquot River, and red maple swamps are also present. The headwater of the Connetquot falls only 1.9 miles from the headwater of the Nissequogue River on the north shore and thus the two bodies of water form a nearly continuous habitat from the Great South Bay to the Long Island Sound.

Champlin Creek and Orowoc Creek represent two fresh water coastal streams that also are home to fresh water marshes upstream (Dowhan et al., 1997a). Several communities including a pitch pine swamps, peat bogs, and shallow ponds can be found in this complex. Swan River and Beaverdam Creek are other examples of fresh water stream habitats occurring in the south shore outwash plain. At the headwaters of Yaphank Creek, extensive emergent fresh water marshes have been observed.

Many streams located in the south shore outwash plain are dammed. As a result several ponds and other lacustrine environments exist along these streams. There also exist some small ponds that appear in small depressions where the ground surface intercepts the water table. Many of these are not natural features, but were constructed to enhance local real estate values.

The Peconic River – Pine Barrens community describes an area that stretches south and east from the headwaters of the Carmans River and Peconic River to the Shinnecock Canal. A rich diversity of fresh water habitats is associated with this region and several unique habitats occur in and around the Pine Barrens. Fresh water ecological communities found in the Peconic River – Pine Barrens community include (CPBJPPC, 1995; Cashin Associates, 2004):

- coastal plain Atlantic white cedar swamp
- coastal plain stream
- coastal plain poor fen
- coastal plain pond
- coastal plain pond shore
- Pine Barrens shrub swamp
- red maple – black gum swamp
- intermittent stream
- shallow emergent marsh
- fresh water tidal marsh

Overall, the Peconic River – Pine Barrens system represents 4,300 acres of NYSDEC regulated fresh water wetlands with the Peconic River accounting for over 2,000 of those acres and the Carmans River covering nearly 1,000 acres (CPBJPPC, 1995). The Carmans and Peconic Rivers, as with the smaller streams in this area, have been dammed to create ponds and lakes of various sizes. This means that many of the well-established habitats of the region are actually anthropogenic in nature (Cashin Associates, 2002; Cashin Associates, 2004).

Besides the two major river systems, another 162 mapped wetlands account for the remainder of the region’s fresh water acreage with seven wetlands falling between 15 and 100 acres and the other 155 being smaller than 15 acres. The most common wetland found throughout the system is the red maple – black gum swamp (CPBJPPC, 1995). A variety of coastal plain ponds and pond shores have unusual habitats, formed where water levels fluctuate greatly, and often having low levels of nutrients and high acidity. Examples of coastal plain ponds found within this region include:

- Calverton Ponds
- Sweezy Pond
- Prestons Pond
- Fox Pond
- McKay Lake
- Overton Pond
- Currans Road South Pond
- Randall Road North Pond
- Lake Panamoka
- Artist Lake
- Coreys Pond

White cedar swamps, formerly extensive in the Peconic River – Pine Barrens region, have been reduced to a few scattered remnants due to historical logging and draining. The largest white cedar swamp remaining in Suffolk County occurs in Cranberry Bog County Park in Southampton Town near the Peconic River (CPBJPPC, 1995). In addition, Cranberry Bog County Park is also home to one of the largest coastal plain poor fen in Long Island.

Intermittent streams are found throughout the upper portions of the Peconic River and can be found adjoining red maple swamps, tussock-sedge marshes and wet meadows. These habitats are prevalent west of Wading River – Schulz Road (Cashin Associates, 2004). Pine barren shrub swamps may also be found in the uppermost reaches of the Peconic River – Pine Barrens watershed. Shallow emergent marshes are found on the edges of shallows of ponds, lakes, and streams within the region while fresh water tidal marshes are often located in the tidal portions of the larger river systems, often in their tidal tributaries.

The east end of Suffolk County can be divided into two distinct geographic areas. The North Fork lies to the north and east of Riverhead and the South Fork is south and east of Riverhead.

Both forks were shaped by moraines deposited during glacial periods. The North Fork is characterized by its surrounding waters, the Long Island Sound to the North and the Peconic Bay to the south, while the South Fork is bounded by the Peconic Bay to the North and the Atlantic Ocean to the south. In between, and to the east of, the two forks can be found several major islands including: Shelter Island, Gardiner's Island, Plum Island, and Fishers Island.

The fresh water wetlands found on the North and South Forks are generally similar in nature. The following communities can be found in the east end of Suffolk County:

- coastal plain Atlantic white cedar swamp
- vernal pool
- red maple – black gum swamp
- highbush blueberry bog thicket
- sea level fen
- coastal plain poor fen
- maritime fresh water interdunal swales
- Pine Barrens shrub swamp
- coastal plain pond shore
- shrub swamp
- shallow emergent fresh water marsh
- eutrophic pond
- coastal plain pond
- coastal plain stream
- intermittent stream

The USFWS and others have identified several significant freshwater habitats on the east end of Suffolk County that include (Dowhan et al., 1997b):

- Long Pond Greenbelt

- South Fork Atlantic beaches
- Montauk Peninsula
- Mashomack Preserve

The Long Pond Greenbelt habitat is composed of a network of contiguous ponds, streams, wetlands, and adjacent upland woods from Sagaponack Inlet on the south shore of the South Fork to Sag Harbor on the Peconic Bay. Coastal plain ponds occur between Bridgehampton and Sag Harbor and include (Dowhan et al., 1997c):

- Poxabogue Pond
- Little Poxabogue Pond
- Slate Pond
- Black Pond
- Crooked Pond
- Long Pond
- Lily Pond
- Round Pond

The network of coastal plain ponds is connected by a series of fresh water streams that lead to a red maple – black gum swamp in its southernmost reaches near Sagaponack Pond. Also found within this system are Pine Barrens shrub swamps, wetland shrub thickets, and coastal plain pond shore communities.

The Montauk Peninsula represents that further east component of the east end region and is exposed to greatly different climatic conditions than western Suffolk County. Differences include moderated temperatures, higher winds, and greater precipitation. Within the region several types of fresh water wetlands can found including:

- coastal plain ponds
- intermittent streams
- maritime freshwater interdunal swales

- red maple – black gum swamps

.Little Reed Pond is a transitional habitat between brackish and fresh water, while Big Reed and Fort Pond are fresh water coastal plain ponds. Napeague beach contains one of the largest remaining areas of undeveloped beach on Long Island with extensive dunes and maritime interdunal swale habitats (Dowhan et al., 1997d).

The South Fork Atlantic Beach community is identified as the area between the eastern end of Shinnecock Bay and the Amagansett National Wildlife Refuge in East Hampton. This area of Suffolk County is unique in that the coastal areas are connected directly to the mainland and are not separated by barrier beaches as is much of western Suffolk County and Long Island. As a result the Atlantic Beach complex contains several backbarrier fresh water coastal plain ponds and maritime fresh water interdunal communities (Dowhan et al., 1997e). The backbarrier coastal plain ponds of the complex include:

- Halsey Neck Pond
- Coopers Neck Pond
- Agawam Lake
- Old Town Pond
- Wickapogue Pond
- Phillips Pond
- Sayre Pond
- Jule Pond
- Channel Pond
- Wainscott Pond
- Lily Pond

Mashomack Preserve on Shelter Island falls between the North and South Forks of the east end. Mashomack is a natural area of over 2,000 acres that was preserved by the Nature Conservancy in 1980 (Shelter Island, 2004). Mashomack contains a variety of fresh water habitats including:

- coastal plain streams
- fresh water tidal marshes
- pitch pine swamps.

The Pine Swamp complex at the western edge of the Preserve is designated a fresh water wetland of unique local importance by the NYSDEC.

Salt marshes along the Peconic Bay system on both forks often grade into fresh water wetlands along their upper reaches. There are no major stream systems draining these narrow peninsulas, but small, groundwater-fed streams sometimes are found at the upland edge of the salt marsh systems. In one or two cases, the fresh water part of a coastal marsh system has been tidally-isolated by roads or other impoundments. It is not clear if these wetlands were originally more salt marsh than fresh marsh prior to the restriction of tidal flows.

### 5.9 Notable Suffolk County Fresh Water Wetlands Mosquitoes

Mosquitoes utilize wetland habitat for a variety of functions including breeding, feeding, and overwintering. After hatching from an egg, mosquitoes develop in an aquatic environment as an air-breathing filter feeder and undergo metamorphosis through four larval stages prior to becoming a non-feeding pupa. Mosquitoes become capable of flight after emerging from the pupal stage. Males and females tend to feed on plant nectars to fulfill daily energy needs; however, in almost all mosquito species the female requires a blood meal for her eggs to mature. Most species have general preferences of prey for blood, and some preferences are quite specific (CA-CE, 2004).

All mosquitoes require damp to wet conditions to lay their eggs. Univoltine species reproduce once a year, while multivoltine species lay eggs that hatch at various times throughout the year. Desiccation tolerant mosquitoes require that their eggs dry out prior to further development and tend to hatch in “broods” as conditions result in eggs developing at the same time. Mosquitoes whose eggs are dessication intolerant do not dry out and often hatch in a more diffuse manner. Some mosquitoes prefer organically polluted water as breeding sites (some species actually require it, such as *Cx. pipiens* and *Cx. restuans*) and others can tolerate or need salt water (CA-CE, 2004).

Thirteen species representing six genera may inhabit the freshwater wetlands in the region and are identified as of importance to the SCVC (D. Ninivaggi, SCVC, personal communication, 2004) (see Table 5-10).

Table 5-10. Freshwater Mosquito Species of Suffolk County and Habitat Preferences

| **Species** | **Habitat Preferences** | **Estimated flight range** |
|---|---|---|
| *Aedes vexans* | Fresh flood water, upper salt marsh | 5-10 miles |
| *Anopheles quadrimaculatus* | Fresh water swamps, brackish water swamps, standing polluted water, containers | Less than 1 mile |
| *Culex pipiens/ restuans* | Fresh water swamps, brackish water swamps, standing polluted water, containers, catch basins | 1-2 miles, usually much less |
| *Culex salinarius* | Fresh flood water, upper salt marsh flood water, brackish water swamps, containers | 1-2 miles, usually much less |
| *Culex territans* | Fresh water swamps with clean water and abundant herptilian populations | Less than 1 mile |
| *Culiseta melanura* | Red maple – black gum and Atlantic white cedar swamps, fresh flood water, containers | 5 miles |
| *Coquillettidia perturbans* | Woodland pools, emergent marshes, fresh water swamps, roadside ditches with emergent vegetation | 1-2 miles or more |
| *Ochlerotatus stimulans* | Woodland pools, fresh water swamps, roadside ditches | Less than 1 mile |
| *Oc. abserratus* | Red maple – black gum swamps, bogs, woodland pools, roadside ditches | Less than 1 mile |
| *Oc. trivittatus* | Fresh flood water, upper salt marsh flood water, recharge areas | Less than 1 mile |
| *Oc. canadensis* | Fresh flood water, especially woodland pools | Less than 1 mile |
| *Oc. triseriatus* | Fresh flood water, salt marsh flood water, tree holes, containers | Less than 1 mile |

(CA-CE, 2004)

*Aedes vexans* is a multivoltine, freshwater, desiccation tolerant mosquito. It often uses fresh flood water habitats in Suffolk County and prefers less salty environments when compared to *Oc. sollicitans*. *Ae. vexans* lays it eggs in ground depressions inundated by fresh flood waters and its broods tend not to emerge as frequently as *Oc. sollicitans,* often occurring in response to rainfall or river flooding. *Ae. vexans* is an aggressive biting mosquito that also can fly large distances from its breeding place. Species that have similar life-cycles to *Aedes vexans* include:

- *Ps. ciliata*
- *Ps. howardi*
- *Oc. trivittatus*
- *Ps. columbiae*
- *Ps. ferox*

(CA-CE, 2004)

*Anopheles quadrimaculatus* is a species of continuous breeders that lay their non-desiccation tolerant eggs in pristine fresh water swamp habitats. Typical breeding habitats are similar to those inhabited by *Oc. abserratus,* however *An. quadrimaculatus* will normally be found in these environs later in the breeding season. Larvae often develop in fresh water swamps in bogs and multiple generations are produced annually. *An. quadrimaculatus* is also known as the species most likely to transmit malaria in Suffolk County. Similar species found in Suffolk County include *Cx. territans* and *Ur. sapphirinna* (CA-CE, 2004).

*Culex pipiens* and *Cx. restuans* are difficult to differentiate, and so are often grouped as "*Culex spp.*" These mosquitoes are multivoltine, desiccation tolerant mosquitoes. They breed primarily in polluted fresh water environments and do not travel far. They will also breed in drainage structures, septic ditches, and polluted ponds or puddles. Larvae thrive in polluted water habitats with high organic content such as rotting vegetation, decaying animal wastes and septic seepage. They are not aggressive feeders on people and apparently prefer to feed on birds. By all accounts, they are key to the cycling of WNV in Suffolk County (CA-CE, 2004).

*Culex salinarius* is a multivoltine, salt tolerant, mosquito that lays non-desiccation tolerant eggs in brackish or fresh water habitats. Larvae hatch after being deposited in standing waters from lunar tides and grow in brackish water swamps. *Cx. salinarius* is also capable of breeding in fresh water habitats but generally reach greatest concentrations in areas closer to the coast (CA-CE, 2004). The role of *Cx. salinarius* in WNV transmission in Suffolk County may have been underappreciated due to the difficulty in identifying it separately from *Cx. pipiens/restuans*. 1995 efforts found a much higher proportion of "*Culex spp.*" mosquitoes were actually *Cx. salinarius* than had been expected (S. Campbell, SCDHS, personal communication, 2006)

The frog feeding mosquito, *Culex territans,* is a herptilian feeder that obtains most of its blood meals from amphibian hosts. The mosquito breeds in pristine fresh water swamps and bogs where frogs are common and emerges from hibernation earlier than most mosquito species to take advantage of the large populations of frogs that breed early in the year. Other mosquito species known to have similar life cycles in Suffolk County include *An. quadrimaculatus* and *Ur. sapphirinna* (CA-CE, 2004)

*Culiseta melanura* is a multivoltine, freshwater, desiccation intolerant mosquito. Eggs are laid directly on the water and larvae develop in swamps and bogs. Larvae of the species overwinter in cedar and red maple swamps of Suffolk County. The larvae are frequently found in "crypts" under the roots of trees. *Culiseta melanura* feeds exclusively on birds (CA-CE, 2004).

Recent studies indicate that the population of *Culiseta melanura* may be increasing rapidly in the region. This is thought to be due to a significant rebound in the numbers of red maples present throughout Suffolk County. Red maple populations were observed to be well below normal in the earlier half of the twentieth century due to logging and clearing activities. The hurricane of 1938 subsequently cleared many of the remaining red maples and other swamp species on Long Island and throughout New England. Recent decades, with the legal protections now afforded to freshwater wetlands, have seen red maples grow to maturity. Mature trees have more, and larger, crypts in their root areas. *Cs. melanura* uses the crypts under the roots of these trees for overwintering habitat. It follows then that increases in habitat and populations of *Cs. melanura* could be a significant factor in the recent increases in incidences of EEE in the northeast US, because *Cs. melanura* serves as the amplification vector of EEE (CA, 2005b).

*Coquillettidia perturbans* is a univoltine, freshwater, desiccation intolerant mosquito. Its larvae attach themselves to the roots of emergent vegetation. The mosquito overwinters as larvae in various stages of development. It appears to generate broods, but the different emergences from fresh water swamps signal the timing associated with the different instars of the overwintering larvae. It can migrate several miles in search of a blood meal (CA-CE, 2004).

*Ochlerotatus stimulans* is a univoltine species that utilizes woodland pool habitats. *Oc.* s*timulans* lays desiccation tolerant eggs in ground depression in wooded areas and larvae develop in woodland pool habitats. Larvae are often found in a variety of leaf-lined vernal pools that are flooded by a combination of spring rains and snow melts (CA-CE, 2004).

*Ochlerotatus abserratus,* is a univoltine species found in swamps and bogs throughout Suffolk County. It is characterized by desiccation tolerant eggs laid above the water line in saturated soils and larvae that develop in palustrine ecosystems. Often the species is found in specific swamp habitats such as red maple – black-gum, cattail, or sphagnum swamps (CA-CE, 2004).

*Ochlerotatus trivittatus* has a life-style akin to *Ae. vexans*, and so is a multivoltine, desiccation tolerant mosquito. It breeds in fresh water environments, and is especially common in recharge basins that retain water intermittently. It is an aggressive biter of people, but has a short flight range (CA-CE, 2004).

*Ochlerotatus canadensis* emerges in early spring but may have additional broods in the summer, and is a fresh water, desiccation tolerant mosquito. Eggs are laid in a variety of transient and permanent water environments and larvae develop in a wide variety of fresh water habitats. In some years the species will experience multiple broods if heavy rains re-flood their fresh water wetland habitats. It does not venture far from its larval habitat, but has been described as a fierce biting mosquito (CA-CE, 2004).

*Ochlerotatus triseriatus* is a multivoltine, fresh water desiccation tolerant mosquito. *Oc. triseriatus* deposits it eggs in bands just above the waterline in natural and manmade containers. It typically uses abandoned tires, the anthropogenic equivalent to natural tree holes, as habitat, and prefers polluted waters. It does not fly far from its breeding points (CA-CE, 2004).

## 5.10 Primary Study Areas and Wertheim National Wildlife Refuge OMWM Demonstration Project Site Descriptions

Tidal and freshwater wetlands were selected from the north and south shores of Suffolk County for study as “Primary Study Areas” (PSAs). These 21 wetlands were chosen because of their exceptional environmental quality or for their value as archetypes for other sites in the County. In addition, they have also been used to illustrate and demonstrate examples of generic impacts associated with some of the proposed management actions under the Long-Term Plan. The locations of these sites are shown in Figure 5-7 (along with the Wertheim National Wildlife Refuge OMWM Demonstration Project). Each PSA was also important to the County’s vector control program as a known mosquito breeding area, a site managed by the Division of Vector Control, or a control site for the purposes of this project. The Wertheim site is included in this discussion because it was also used as an exemplar for some of the generic impacts discussed in this Environmental Impact Statement.

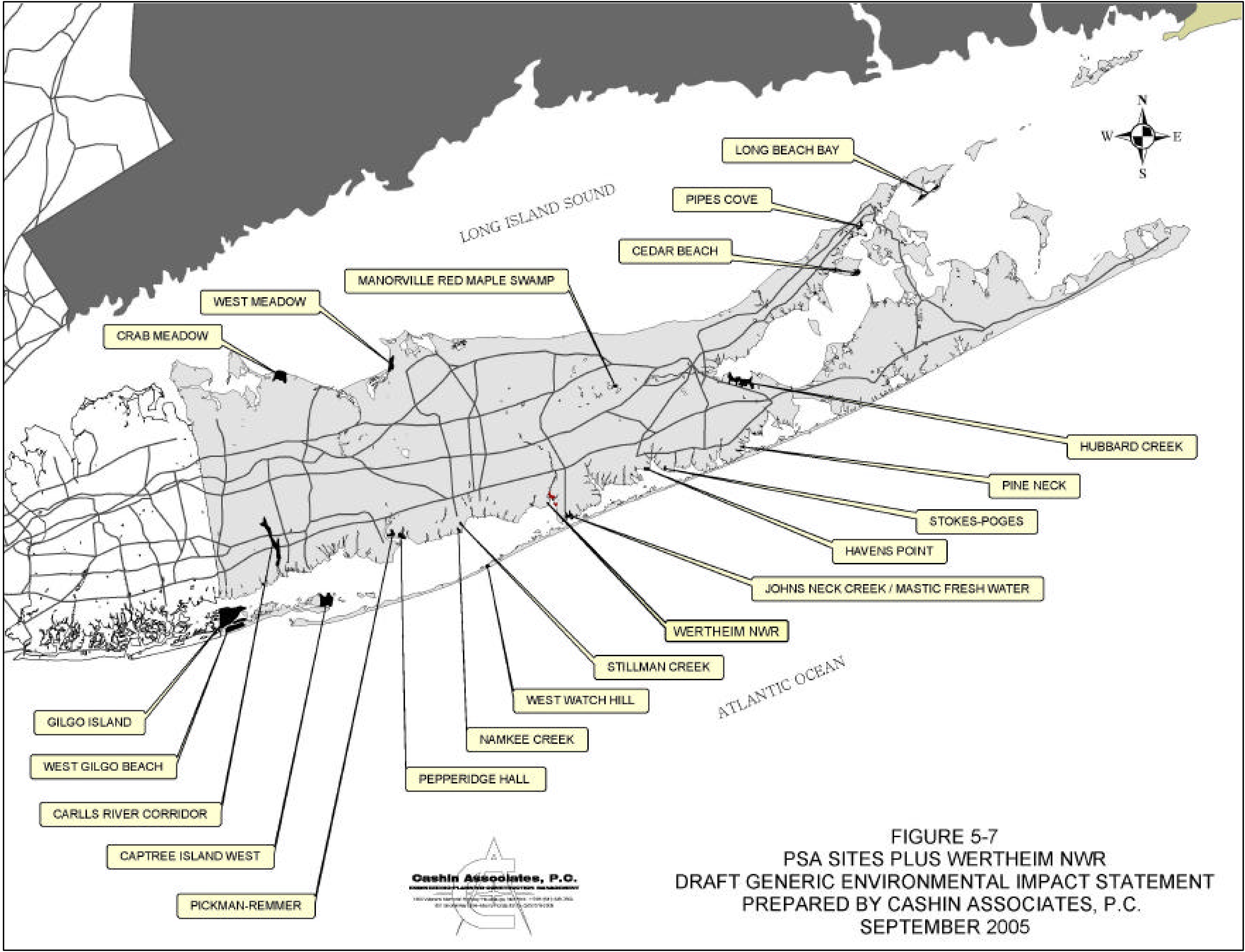


FIGURE 5-7
PSA SITES PLUS WERTHEIM NWR
DRAFT GENERIC ENVIRONMENTAL IMPACT STATEMENT
PREPARED BY CASHIN ASSOCIATES, P.C.
SEPTEMBER 2005

Each of the PSA wetlands was researched, sampled, and mapped. This was an extensive effort, designed to generate marsh specific information to enable the project to assess impacts of marsh management choices in well-defined settings.

Sampling at the Wertheim NWR OMWM Demonstration Project site began in September 2003, and has continued for the length of the project. The scope and methods employed in the sampling there are discussed in more detail in Section 6.

### 5.10.1 PSA Methodology

Prior to any field work, each site was researched. Internet and other library searches were conducted to find any previously conducted work. Aerial photographs, USGS quad maps, census data, and SCVC records were reviewed. Preliminary reports on each site were compiled and circulated to SCVC and SCDHS for comment.

A representative portion of each PSA was selected as a study area. At a minimum, study areas included two to four primary ditches, tidal creeks, and upland areas. Observations were recorded for PSA topography, vegetation type, wildlife, waterbodies present (*i.e.* tidal creeks, ponds and pannes), upland development, and stormwater discharges.

Population estimates were obtained from the US Census website. Population estimates were made within half mile and two mile radii of the wetlands. Census blocks were included in the population estimates of the radii intersected the majority of the blocks.

Water quality parameters were measured and recorded. Temperature, salinity, and dissolved oxygen concentrations were measured in ditches, pannes, ponds and tidal creeks using a YSI 30 salinity-temperature-conductivity meter or a DUR OX 325 Oxi 340i oxygen meter. Locations were selected in two or more ditches from the mouth of the ditch in the tidal channel to the head of the ditch. To improve field mapping accuracy, locations were frequently selected near cross ditches. Locations were identified on large-scale aerial maps that were utilized in the field.

Tidal creeks, ponds, and pannes were identified on the aerials. Ditch orientation, spacing intervals, occlusions, bank erosion, water movement, depth, and substrate type were recorded. All sampling locations were recorded on a GIS map overlaid on a 2001 aerial map.

To measure the magnitude of tidal inundation at each PSA, wooden stakes coated with water-soluble glue were placed throughout each marsh prior to a lunar high tide. As the high tide rose, the glue was washed away to the elevation of high tide. After the high tide receded, measurements of the stakes and glue line were recorded. The measurement of the height of the stake and the distance from the marsh surface that the glue was washed away from the tide determined the amount of tidal inundation.

Dominant marsh vegetation was identified and recorded on the aerial maps. Marsh vegetation was identified according to the NYSDEC zonation designations for intertidal and high marsh (Table 5-11). Intertidal marsh is defined as

> the vegetated wetland zone lying between average high and low tidal elevations in saline waters. The predominant type of vegetation in this zone is low marsh cordgrass (*Spartina alterniflora).*

High marsh is defined as

> the normal upper most tidal wetland zone usually dominated by salt meadow grass (*S. patens*) and spike grass (*Distichlis spicata*). This zone is periodically flooded by spring and storm tides and is often vegetated by low vigor *S. alterniflora*, and seaside lavender (*Limonium carolinianum*). The upper limits of this zone often include black grass (*Juncus gerardi*), chairmaker's rush (*Scirpus* spp.), marsh elder (*Iva frutescens*) and groundsel bush (*Baccharis halmifolia*).
>
> (Niedowski, 2000).

Upland areas and growth of the common reed *Phragmites australis* were also identified. Vegetation locations were recorded in the field and subsequently transferred to GIS maps.

Table 5-11. NYSDEC Marsh Zonation Designations

| **Marsh Designation** | **Common Name** | **Scientific Name** |
|---|---|---|
| **Intertidal Marsh** | low marsh cordgrass | *Spartina alterniflora* |
| **High Marsh** | salt meadow grass | *Spartina patens* |
| | spike grass | *Distichlis spicata* |
| | low vigor cordgrass | Short form of *S. alterniflora* |
| | seaside lavender | *Limonium carolinianum* |
| | black grass | *Juncos gerardi* |
| | chairmakers rush | *Scirpus* spp. |
| | marsh elder | *Iva frutescens* |
| | groundsel bush | *Baccharis halmifolia* |

NYSDEC, 1999

### 5.10.2 Crab Meadow

*Selection Criteria and Current Condition*

Crab Meadow was chosen as a PSA because it is a major north shore marsh with no current vector control problems. Crab Meadow is one of the very few large areas of undeveloped salt marsh remaining on Long Island's north shore. These salt marshes are included in the New York Natural Heritage Program Reference Wetlands.

*Location, Size and Ownership*

Crab Meadow is located in the Town of Huntington, west of Eaton's Neck on the North Shore, approximately one and one-half miles north of the Village of Northport. Crab Meadow is owned by the Town of Huntington.

The entire marsh is approximately 121 hectares (300 acres). The section of marsh west of the tidal creek was the focus of this study. This portion of the marsh studied measures approximately 21 hectares (53 acres).

*Topography and Waterbodies*

Crab Meadow is situated within Hydrogeologic Zone VIII, as delineated in the Long Island 208 Study. This zone is defined as the north shore shallow flow system, in which the groundwater primarily moves laterally. Some upward flow may take place in this area as the groundwater discharges to surface water bodies.

A single tidal inlet connects to a multi-branched tidal creek system throughout the entire marsh. The main tidal creek empties into the Long Island Sound. Two small creek systems drain into the marsh from the south. These systems lie on either side of the golf course, located to the south of the marsh. Both systems contain dammed ponds.

Numerous ponds and pannes were observed at Crab Meadow. Ponds ranged in size from 2 x 1 meters (6.5 x 3.2 feet), 8 centimeters (3 inches) deep to 20 x 10 meters (66 x 33 feet), 2 cm (0.7 inches) deep. The deepest pond was 18 cm (7 inches) and 5 x 3 meters (16 x 10 feet) wide, which contained an abundant amount of fish and grass shrimp. In addition to naturally occurring ponds, an artificial structure full of water was noted in the northern portion of the marsh. The structure is approximately 1 x 1½ meters (3 x 5 feet) in size and 40 cm (16 inches) deep. A moderate number of grass shrimp and fish were also observed in this structure.

### *Land Use and Population Density*

Crab Meadow is bordered by undeveloped woodland, county parkland and a golf course to the south, beach-front (some seasonal) homes along the barrier beach to the north, low density residential development to the east (half acre to one acre lots) and higher density houses to the west (quarter acre and smaller lots). The population is 2,164 within one-half mile of Crab Meadow, and 17,603 within two miles.

### *Tidal Characteristics*

#### Tidal Range

Crab Meadow is not tidally restricted. Based on tidal information for nearby Eaton's Neck Point, the mean tidal range for Crab Meadow is approximately 7.1 feet. The spring tidal range is approximately 8.2 feet and the mean tide is 3.9 feet.

#### Tidal Inundation

In order to assess the amount of tidal inundation on the marsh surface, a tidal inundation study was completed during the lunar high tide in November 2004. Before the lunar high tide, stakes were placed in areas of standing water throughout the high marsh on November 24th and inundation measurements were collected on November 27th.

Nine stakes were placed throughout the marsh at Crab Meadow. Stake S1 was placed adjacent to the northern boundary ditch. This area received 30.5 cm of water. Stake S2 was placed in high marsh vegetation consisting of *Spartina patens* and *Distichlis spicata*. This area received 33 cm of water. Stake S3 was placed in a small pond among mixed vegetation. This pond received 30 cm of water. Stake S4 was placed in high marsh vegetation in the upper portion of the marsh. This area received 32.5 cm of water. Stake S5 was placed just west of Stake S4 in mixed low marsh/high marsh vegetation. This area received 33 cm of water. Stake S6 and S7 were placed in the upper marsh adjacent to the northern stand of *Iva frutescens*. Vegetation surrounding these stakes was a mix of *Spartina patens, Distichlis spicata* and *S. alterniflora.* Stake S6 received 30 cm of water and stake S7, placed west of stake S6 received 33.5 cm of water. Stake S8 was placed in high marsh adjacent to a terminus of a tidal creek branch. This area received 29 cm of water. Stake S9 was placed east of stake S8 in the same panel, which also received 29 cm of water.

The amount of inundation that occurred throughout the marsh was generally consistent. Stakes S8 and S9 received slightly lower amounts of inundation because the elevation at these locations is slightly higher than the rest of the marsh.

Table 5-12. Crab Meadow Tidal Inundation

| **Stake** | **Marsh Placement** | **Tidal Inundation (centimeters)** |
|---|---|---|
| S1 | Adjacent to ditch | 30.5 |
| S2 | High marsh | 33 |
| S3 | Pond | 30 |
| S4 | High marsh | 32.5 |
| S5 | Mixed vegetation | 33 |
| S6 | Mixed vegetation | 30 |
| S7 | Mixed vegetation | 33.5 |
| S8 | High marsh | 29 |
| S9 | High marsh | 29 |

### *Stormwater*

No stormwater discharge pipes were observed at Crab Meadow. The drainage system to the west is considerably larger than that to the east (the system to the east is essentially bounded by NYS Route 25-A; the system to the west extends into the hamlet of East Northport). There can be considerable run-off generated by the steep topography, and much of that will be directed into the southwest portion of the salt marsh.

### *Water Quality*

Water quality measurements were collected from the head, mouth, and mid-point sections of the main tidal creek and three selected ditches (D1, D2 and D3). All ditches were analyzed at low tide.

Ditch D1 is approximately 279 meters (915 feet) in length, running north to south, in the northeastern portion of the marsh. Ditch D2 is approximately 176 meters (577 feet) in length, running from west to east in the northwestern portion of the marsh. Ditch D3 is approximately 168 meters (550 feet) in length, running from west to east in the southwestern portion of the marsh.

Temperature appeared to increase slightly from the head to the mouth of the ditches. Salinity remained constant across the marsh, while dissolved oxygen varied slightly. Lower dissolved oxygen levels were recorded at the head of ditch D3. This may be due to vegetation occluding this portion of the ditch.

Table 5-13. Crab Meadow Water Quality Data

| **Station** | **Sample Location Characteristics** | **Water Depth (centimeters)** | **Temp. (C)** | **Salinity (ppt.)** | **DO (mg/L)** |
|---|---|---|---|---|---|
| TC-A | *Spartina alterniflora* | - | 11.8 | 12.0 | 9.1 |
| TC-B | *Spartina alterniflora* | - | 15.4 | 2.0 | 9.4 |
| TC-C | *Spartina alterniflora* | - | 13.6 | 0.1 | 5.62 |
| D1A | *Spartina alterniflora* | 5 | 12.9 | 22.6 | 6.8 |
| D1B | *Spartina alterniflora* | 2 | 9.7 | 22.0 | 9.8 |
| D1C | *Spartina alterniflora* | 4 | 9.7 | 22.1 | 7.1 |
| D2A | *Spartina alterniflora* | 4 | 12.9 | 19.0 | 8.3 |
| D2B | *Spartina alterniflora* | 2 | 12.4 | 21.0 | 7.3 |
| D2C | *Spartina alterniflora* | 2 | 11.8 | 21.0 | 5.8 |
| D3A | *Spartina alterniflora* | 3 | 18.0 | 23.0 | 7.1 |
| D3B | *Spartina alterniflora* | 2 | 16.5 | 23.0 | 6.9 |
| D3C | *Spartina alterniflora* | 10 | 11.4 | 22.0 | 3.8 |

Note: Samples collected on 10/18/04; during low tide (9:00 a.m.)
D = ditch TC = tidal creek

### *Ecology*

#### Tidal Vegetation

The study area of Crab Meadow is primarily dominated by *Spartina alterniflora*. Tall-form *S. alterniflora* is present along the edges of ditches and the branches of the tidal creek. Throughout the marsh, sections of low marsh are mixed with *Distichlis spicata* and *Spartina patens*.

A large stand of *Iva frutescens* is located along the northern boundary of the marsh, approximately 53 meters (175 feet) at the widest point. *Iva frutescens* and a relatively thin border of *Phragmites australis* dominate the western edge of the marsh. The uplands, where undeveloped, largely consist of second-growth hardwood forest.

#### Phragmites

Besides the thin border along the western portion of the marsh, *Phragmites australis* is notable through its general absence from the marsh.

#### Wildlife

Rainwater killifish (*Lucania parva*) were observed in moderate numbers toward the western end of ditch D2, as the ditch branches off into a series of small ponds. The vegetation near these ponds appears to be dead *S. patens*. Fish were not observed in either ditch D1 or ditch D3.

Varying amounts of fish were observed in the ponds at Crab Meadow. The amount of fish in the ponds appeared to increase with pond depth. Moderate numbers of ribbed mussels (*Geukensia demissa*), snails (*Melampus bidentatus*), and fiddler crab (*Uca pugnax*) holes were noted along the ditches and tidal creeks in areas of open mud and sparse vegetation. Canada geese (*Branta canadensis*) were observed utilizing the marsh during low tide and in the high marsh during the lunar high tide. Several osprey nest platforms are located throughout the marsh, some of which had signs of nesting activity.

### *Mosquito Habitat/History*

#### Ditching and Ditch Condition

Parallel ditches cut through the majority of the marsh, perpendicular to the tidal creek. Ditches are spaced approximately 36.5 meters (120 feet) apart and are up to 293 meters (960 linear feet) in length. Some grid ditching occurs in the northwestern corner and other areas throughout Crab Meadow. All ditches appeared to have clear connections to the tidal creek.

Three ditches (D1, D2 and D3) were analyzed for general ditch characterization. All three ditches had a muddy substrate, except for the northernmost portion of ditches in the north section of the marsh, where the substrate was more firm and sandy. Ditch D2 becomes occluded with vegetation (*S. alterniflora, S. patens,* and *D. spicata*) towards the head of the ditch, before the ditch forms a series of pannes and ponds.

#### Pesticide Applications

Aerial larviciding does not take place on this marsh due to the low numbers of mosquitoes. No OMWM techniques have been installed at Crab Meadow.

### 5.10.3 West Meadow

*Selection Criteria and Current Condition*

West Meadow was selected as a PSA because it is a smaller marsh on the north shore with limited vector control issues.

*Location, Size and Ownership*

West Meadow is located in central Suffolk County on the north shore of Long Island near the hamlets of Stony Brook and Setauket. West Meadow Beach borders the West Meadow marsh on the west while West Meadow Creek meanders north to south through the marsh.

West Meadow is approximately 36 hectares (88 acres) in size. It is bounded by Trustee Road on West Meadow Beach to the west and residential development east of West Meadow Creek.

West Meadow is currently managed by the Ward Melville Heritage Organization (WMHO). WMHO retains ownership rights to the wetland. West Meadow Beach is located at the northernmost end of the marsh, which is owned and operated by the Town of Brookhaven.

*Topography and Waterbodies*

The majority of West Meadow consists of a mix of high marsh/low marsh vegetation, primarily dominated by tall-form *Spartina alterniflora*. High marsh areas consist mainly of *Iva frutescens*, *S. patens*, and *Distichlis spicata* with some *Phragmites australis* and cedar.

West Meadow resides in Hydrogeological Zone VIII, as designated in the Long Island 208 Study. This area is defined as likely to contribute water only to the shallow groundwater flow system and flow in the upper aquifer is essentially horizontal. West Meadow Creek drains a large portion of the hills to the east of the area and the creek has one large offshoot that heads east and splits halfway upstream into two smaller tributaries. The head of West Meadow Creek is an unusually large and deep forked basin that was created by dredging in the 1920s.

Several ponds and pannes were observed at West Meadow. Two small ponds were observed in the high marsh, approximately 5 x 5 meters (16 x 16 feet) and 4 x 2 meters (13 x 6.5 feet) in size. The depths of the ponds were 4 and 24 cm (1.5 and 9 inches) deep, respectively. Pannes ranged in size from 3 x 4 meters (10 x 13 feet) to 25 x 25 meters (82 x 82 feet).

### *Land Use and Population Density*

Land use near West Meadow consists of residential development on large parcels. West of the marsh along Trustee Road were 93 cottages that have since been demolished in January 2005, as part of an agreement in 1996 to return the beach back to the general public.

The population is 3,467 within ½ mile of West Meadow and 19,868 within two miles of the site. The population of the hamlet of Setauket was recorded at 15,931 during the 2000 census and the population of the hamlet of Stony Brook was 13,727.

### *Tidal Characteristics*

#### Tidal Range

West Meadow is connected to the Long Island Sound by West Meadow Creek in the southwest portion of the study area and is not tidally restricted. The mean tidal range of West Meadow, based on the nearest tide location, Port Jefferson, is 2 meters (6.61 feet). The spring tidal range at Port Jefferson is 2.18 meters (7.16 feet) and the mean tide level is 1.07 meters (3.53 feet).

#### Tidal Inundation

In order to assess the amount of tidal inundation on the marsh surface in areas of high marsh, a tidal inundation study was completed during the full moon in December 2004. Before the lunar high tide, stakes were placed in areas of standing water throughout the high marsh on December 10th and inundation measurements were collected on December 11th.

Six stakes were placed in high marsh vegetation, which is limited to the western portion of the marsh. Vegetation consists of *Distichlis spicata, Spartina patens,* and *Iva frutescens*. On average, 50.8 centimeters of inundation reached the high marsh in this region. The adjacent Trustee Road also became flooded because of the lunar high tide.

Table 5-14. West Meadow Tidal Inundation

| Stake | Marsh Placement | Tidal Inundation (centimeters) |
|---|---|---|
| S1 | High marsh | 50 |
| S2 | High marsh | 65.5 |
| S3 | High marsh | 46 |
| S4 | High marsh | 44.5 |
| S5 | High marsh | 50 |

### *Stormwater*

No stormwater discharge pipes were observed at West Meadow.

### *Water Quality*

Water quality measurements were collected from the head, mouth, and mid-point sections of the tidal creek and three selected ditches (D1, D2 and D3). All three ditches were analyzed during low tide.

Overall, temperature slightly increased in a northerly direction across the marsh. Salinity increased slightly towards the mouth of the ditches, while dissolved oxygen decreased.

Table 5-15. West Meadow Water Quality Data

| **Station** | **Sample Location Characteristics** | **Water Depth (centimeters)** | **Temp. (C)** | **Salinity (ppt.)** | **DO (mg/L)** |
|---|---|---|---|---|---|
| TC-A | *S. alterniflora* | - | 12.1 | 25 | 9.8 |
| TC-B | *S. alterniflora* | - | 13.1 | 25.2 | 10.2 |
| TC-C | *S. alterniflora* | - | 13.1 | 20.1 | 11.7 |
| D1A | *S. alterniflora* | 10 | 11.5 | 24.8 | 3.5 |
| D1B | *S. alterniflora, S. patens* | 23 | 10.1 | 23.4 | 4.3 |
| D1C | *S. alterniflora, S. patens* | 10 | 11.8 | 24.3 | 7.1 |
| D2A | *S. alterniflora* | 7 | 12.2 | 25.3 | 2.7 |
| D2B | *S. alterniflora, S. patens, D. spicata* | 14 | 12.3 | 24.6 | 2.87 |
| D2C | *S. patens, I. Frutescens* | 16 | 12.6 | 23.3 | 5.0 |
| D3A | *S. alterniflora* | 4 | 11.7 | 25.6 | 3.1 |
| D3B | *S. alterniflora* | 50 | 12.6 | 26.3 | 6.34 |
| D3C | *S. alterniflora, S. patens, D. spicata* | 5 | 13.0 | 24.9 | 3.8 |

Note: Samples were collected on 11/5/04 at low tide (11:00 a.m.)
D = ditch TC = tidal creek

### *Ecology*

#### Tidal Vegetation

The majority of West Meadow is intertidal vegetation, consisting of tall and short-form *Spartina alterniflora*. Tall-form *Spartina alterniflora* is dominant along the ditches and tidal creek and becomes mixed with and short-form *S. alterniflora* and *Distichlis spicata* between ditches and in the west portion of the marsh.

High marsh vegetation consists mainly of *D. spicata*. *Iva frutescens* is present along the upper limits of the marsh and in areas of higher elevations. *S. patens*, cedar, *Limonium latifolium*, *Salicornia*, and *Solidago virgauria* are found in lesser numbers throughout the high marsh.

#### Phragmites

*Phragmites australis* is noticeably absent from the West Meadow marsh.

Wildlife

Few fish were observed in the ditches during low tide. Moderate numbers of fish and saltmarsh snails were observed the ponds.

*Mosquito Habitat/History*

Ditching and Ditch Condition

West Meadow is grid ditched at 30-meter (100 foot) intervals, with the majority of the ditches occurring in the western and northern portion of the marsh.

Three ditches (D1, D2 and D3) were analyzed for general ditch characterization during low tide. All three ditches bisect the marsh from west to east and are open with clear connections to the tidal creek. The majority of vegetation along the ditches consists of tall-form *S. alterniflora*. Tall-form *S. alterniflora* occludes ditch D2 and ditch D3 at the mid-length portions of the ditches. Vegetation towards the west becomes a mix of *S. alterniflora, D. spicata* and *S. patens*. All ditches terminate in a dense border of *Iva frutescens.* The ditches have a muddy substrate near the tidal creek, which becomes sandier toward the head of the ditches. All three ditches widened extensively at the mouth, almost doubling in width, resulting in the creation of large pannes.

Pesticide Applications

The site has historically not been aerially larvicided and adulticide has not been used in the area. No OMWM techniques have been implemented at this marsh.

### 5.10.4 Captree Island West

*Selection Criteria and Current Condition*

Captree Island West was selected as a PSA because it is the archetype for a “natural” south shore island marsh. The marsh has numerous natural marsh features including large ponds and extensive tidal creeks. It contains remnant ditches and significant, but localized, mosquito breeding on its northern edge that may contribute to problems on the mainland. SCVC is interested in installing fish reservoirs and/or spurs along the upland edge to limit breeding, while minimizing the impact on vegetation. The County believes that alteration of the marsh may not be necessary as mosquito breeding seems to be confined to the northern edge of the island.

### *Location, Size, and Ownership*

Captree Island West is part of the Captree State Park complex, located in the Town of Babylon, west of the Robert Moses Twin Causeway. It is owned by the Town of Babylon and is situated north of the Fire Island Inlet, in Great South Bay. The entire complex is over 120 hectares in size. The size of the area studied measured approximately 640 x 360 meters.

### *Topography and Waterbodies*

Captree Island is situated within Hydrogeologic Zone VII, as delineated in the Long Island 208 Study. This zone is defined as the south shore shallow flow system, in which the groundwater primarily moves laterally. Some upward flow may take place in this area as the groundwater discharges to surface water bodies.

Numerous and extensive tidal creeks drained the island. Many small inlets and islands lined its shoreline. Seven salt pannes, which increased in size in a northeasterly direction, were also present within the study area. Two areas of upland vegetation were located on the western half of the island and a third was located adjacent to Captree Island Road.

### *Land Use and Population Density*

Light residential land use was present on Captree Island West, with 32 homes lining Captree Island Road. Moderate recreational land use was present on the east end of Captree State Park, which contained a fishing pier, boat basin, a promenade, picnic area and several parking fields. The population is approximately 75 within ½ mile of Captree Island West and 195 within two miles of the site.

### *Tidal Characteristics*

#### Tidal Range

The mean tidal range (MHW–MLW) was 30 centimeters (1.0 foot) and the mean spring tidal range (MHHW-MLLW) was 30 centimeters (1.2 feet) (as measured at the Bay Shore benchmark).

#### Tidal Inundation

Five stakes measuring tidal inundation (Stakes S1-S5) were placed south of ditch #1 (D1), on November 8, 2004, several days before the monthly full moon. Retrieval and reading occurred on November 9, 2004. Stake S1 was placed in the upper marsh, along the edge of *Phragmites* *australis* growth. During the incoming tide, this area received 15 centimeters of water. Stake S2 was placed among the short form of *Spartina alterniflora* growing in the upper marsh. Tidal inundation in this area was 24 cm. Stake S3 was placed among *S. patens* plants in the middle marsh and received 27 cm of water. Stake S4 was positioned at the edge of a stand of *P. australis* mixed with *Iva frutescens* in the middle marsh. At high tide, 14 cm of water flooded this area. Stake S5 was placed in a pool, located in the middle marsh, surrounded by *S. alterniflora* (short form). This area received 25 cm of water during the flood tide. Inundation increased from the upper marsh (stake S1) to the middle marsh (stakes S2 and S3). Readings for stakes S3 and S5 were similar because they were placed at approximately the same height in the marsh (Table 5-16).

Table 5-16. Captree Island West-Tidal Inundation

| Stake | Marsh Placement | Tidal Inundation (centimeters) |
|---|---|---|
| S1 | Upper | 15 |
| S2 | Upper | 24 |
| S3 | Middle | 27 |
| S4 | Middle | 14 |
| S5 | Middle | 25 |

### *Stormwater*

No stormwater discharge pipes were observed. Limited stormwater flow onto the marsh may come from Captree Island Road. Stormwater flow from the Robert Moses Causeway may also affect the wetland.

### *Water Quality*

Ditch water depth decreased toward the middle marsh in ditch D1. Water depth values varied along ditch D3 because they were taken at disparate ponds. No samples were taken at station D3B as vegetation blocked water flow. The values for samples taken at station D3C were simply an estimate of water depth taken from the pond’s edge.

Temperature and salinity were relatively constant throughout the ditches and pannes located within the marsh, with values increasing toward the center of the site (station P5) and decreasing as tidal creek influence increased at stations P7 and T1. An occlusion near station D3B precluded the measurement of water quality parameters. The temperature for the sample taken at station D3A was lower and the salinity reading was higher than that of the sample taken at station D3C. In the samples taken at stations along ditch D3, salinity generally decreased from the low marsh to the middle marsh (Table 5-17).

Table 5-17. Captree Island West Water Quality Measurements and Station Water Depth

| **Station** | **Station Location Characteristics** | **Station Water Depth (centimeters)** | **Temperature (ºC)** | **Salinity (ppt.)** |
|---|---|---|---|---|
| D1A | Low marsh, mouth of D3 | 15.2-25.4 | 9.9 | 28.5 |
| D1B | Middle marsh, at junction of pond and ditch | NR | 9.5 | 28.3 |
| D1C | Middle marsh | 1.2 | NR | NR |
| D2A | Low marsh | 30.5 | 9.9 | 29 |
| D3A* | Low marsh, tidal channel | NR | 10.3 | 29.2 |
| D3B | Middle marsh | NR | NR | NR |
| D3C | Middle marsh, pond along D3 | 0-3.8 | 15.2 | 28.1 |
| P1 | Low marsh | 15.2-20.3 | 9.9 | 28.7 |
| P2 | Middle marsh | 2.5-5.1 | NR | NR |
| P3 | Middle marsh, pond | 15.2 | 12.6 | 27.6 |
| P4 | Middle marsh, south of D3 | 2.5-7.6 | 13.2 | 25.4 |
| P5 | Middle marsh, north of D2 | NR | 15.4 | 28.3 |
| P6 | Middle marsh, north of D1 | Plugged w/ vegetation | 10.1 | 28.5 |
| P7 | Middle marsh, between D2 & D3 | 15.2-25.4 | 11.2 | 29.3 |
| T1 | Middle marsh, main channel | NR | 10.3 | 29.2 |

Note: NR-“not recorded” for specified samples.
D = ditch P = panne T = Tributary
A, B, C, D and E = samples taken along ditch
* = samples taken in tidal creek at mouth of ditch

### *Ecology*

#### Tidal Vegetation

A mix of *Spartina patens* and the short form of *S. alterniflora* covered the upper to middle marsh area. *S. patens* are dominant in the eastern portion of the site toward the main tidal channel. Brown macroalgae is present at the pool near station D3C. It was also present in clumps at station P4 and on the surface of the mud in the pool at station P1. The presence of macroalgae in the pool at station P1 indicates that there is sufficient water depth at high tide to support algal growth.

#### Phragmites

Captree Island Road was bordered to the north by *Phragmites australis*. This reed, mixed with *Baccharis halmifolia* extended toward the middle marsh near Stake S4. *Phragmites australis* was present with *Iva frutescens* toward stake S5.

#### Upland Vegetation

Trees in the northwest corner of the study site followed the curve of Captree Island Road and formed the terrestrial edge of the study area. A band of *P. australis* surrounded the pocket of trees on all sides and extended toward the middle marsh. *Phragmites australis*, mixed with *Baccharis halmifolia* bushes, grew from the road toward the middle marsh, near stake S4. A small pocket of *I. frutescens* replaced *B. halmifolia* toward stake S5.

#### Wildlife

Fish, ribbed mussels (*Geukensia demissa*) and mud snails (*Ilyanassa obsoleta*) were common throughout the study area. However, fish were notably absent in areas where the water was stagnant (station D1A) or too shallow (stations P2 and P6). Amphipods, along with dead mud snails, were noted at station P5.

### *Mosquito Habitat/History*

#### Ditching and Ditch Condition

The wetland was extensively ditched, with all ditches in a west-northwest orientation and spaced 60 meters apart. The ditches connected to many salt pannes (seven were noted in the study area) and tidal creek tributaries throughout the wetland. A mud bottom was common along all ditches. Ditch depth increased from the upper marsh (station D1C) to the middle marsh (station D1A and station D1B). In the samples taken at stations P2, P6, and T1, mud depth increased from the low marsh (P2) to the middle marsh (P6 and T1). This unexpected increase in mud depth, in middle marsh, could be the result of a tidal tributary flowing into the pannes located along ditch D2. The single bottom measurement recorded for ditch D3 could also be high due to the presence of the tidal creek comprising part of its length. Occlusions, resulting in areas of extremely shallow (stations D1D, D2B and D2C) or standing water (station D1E), were present along each of the three main ditches sampled. The sample from station D1D was taken along a remnant ditch that no longer served as a viable connection between ditches D1 and D2 because a portion of it had been clogged by plant growth (Table 5-18).

Table 5-18. Captree Island West-Mud Depth

| Station Location | Station Location Characteristic | Mud Depth (centimeters) |
|---|---|---|
| D1A | Middle marsh | 91 |
| D1B | Middle marsh | 91 |
| D1C | Upper marsh | 5-15 |
| D3B | Middle marsh | 91 |
| P2 | Low marsh | 7-10 |
| P6 | Middle marsh | 91 |
| T1 | Middle marsh | 91 |

Note: Table 5-18 only lists samples for which bottom measurements were recorded.
D = ditch P = panne T = tributary
A, B and C = samples taken along ditch

Pesticide Applications

Captree Island West has received larvicide and adulticide applications due to significant, but localized, breeding on its northern edge. OMWM techniques have not been implemented on this island.

### 5.10.5 Havens Point

*Selection Criteria and Current Condition*

Havens Point State Tidal Wetland was selected as a PSA because it is a south shore fringing marsh with few vector control problems. The vegetation pattern of the marsh is characteristic of northeastern marshes. For example, *Spartina alterniflora* (tall form) is present in the low marsh, a mix of *Spartina patens* and *Distichlis spicata* covers the middle marsh, and *D. spicata* dominates the upper marsh. *Phragmites australis*, an invasive species, is also present in the upper marsh and has begun to invade lower areas as well. The presence of this plant tends to coincide with ditch erosion and blockage, leading to standing water and possibly the creation of mosquito breeding areas.

*Location, Size, and Ownership*

The Havens Point State Tidal Wetland, in the Town of Brookhaven, is owned by NYSDEC. It is located in East Moriches, approximately 18.5 kilometers south of Montauk Highway, between Harts Cove and Seatuck Cove, and across from Moriches Inlet. This wetland has undergone restoration by the Long Island Wetland Restoration Initiative (LIWRI). Suffolk County Vector Control works in partnership with the USFWS, NYSDEC, Ducks Unlimited, and other occasional cooperators, as part of LIWRI. LIWRI's goal is to restore and enhance wetlands damaged by dredge and fill projects, systematic grid ditching for mosquito control, *Phragmites australis* control and to protect critical environmental habitats found on Long Island.

The entire marsh, located on the eastern shore of the State Conservation Area, is approximately 3.76 hectares acres in size. Approximately 2.76 hectares (73 percent) were studied.

*Topography and Waterbodies*

The Havens Point State Tidal Wetland is situated within Hydrogeologic Zone VI, as delineated in the Long Island 208 Study. This south shore zone is a 'surface water impact area,' where groundwater discharges to Moriches Bay and the eastern portion of Great South Bay. Any contaminants present in the groundwater can have a major impact on surface waters in this area as flushing rates in this part of the Bay are low.

Hard, sandy soils, and even plant cover, due to a mix of *S. alterniflora* (short form) and *S. patens*, dominated the lower marsh of the study site. In the middle marsh, plant cover was even, but the soil was muddy. Upland topography consisted of clumps of grass and thick stands of *P. australis* (approximately 3.3 meters tall), along with wet muddy sediment. Thick stands of *P. australis* and muddy sediment were particularly prevalent near the pond.

A bell-shaped pond (approximately 60 x 38 meters) was located between the upland and the terrestrial border of the marsh. The pond contained approximately 10 centimeters of water and 45 centimeters of mud. Water movement was observed. A small creek branching from ditch 2, near the 2nd tidal inundation stake, had eroded banks and minimal water movement. The creek ended in a small pool that had a muddy bottom (60 centimeters deep).

*Land Use and Population Density*

The entire area was open space, with approximately 75 percent covered by wetlands and 25 percent covered by forest. Residential plots (approximately 0.2 hectares in size) bordered the wetland to the north. The population is approximately 337 within ½ mile of Haven's Point and 6,298 within two miles of the site.

### *Tidal Characteristics*

#### Tidal Range

The mean tidal range (MHW–MLW) was 80 centimeters (2.9 feet) and the mean spring tidal range (MHHW-MLLW) was 100 centimeters (3.5 feet) (as measured at the Moriches Inlet, Moriches Bay).

#### Tidal Inundation

The wetland is exposed to a long fetch across Moriches Bay. Erosion from wave energy has exposed the roots of *Spartina alterniflora* plants growing along the shore.

Four stakes measuring tidal inundation (stakes S1-S4) were placed in the marsh on November 10, 2004, within two days of the monthly full moon. Retrieval and reading occurred on November 11, 2004. Stake S1 was placed in the low marsh, immediately west of the *Iva frutescens* and *P. australis* line bordering the seaward berm. Stake S1 revealed that the low marsh received 10 centimeters of water. Stake S2, placed near a small pool and approximately 6.0 meters from the first major parallel ditch, revealed the lower middle marsh received 13 centimeters of water. Stake S3 was placed in the upper middle marsh, near the entrance to the pond, revealed this area received 18 centimeters of water. Stake S4 was placed in the upper marsh, north of the pond and *P. australis* at the terrestrial border. During high tide, this area received 14 centimeters of water. The results indicate that inundation increases from the low marsh to the upper marsh, with the middle marsh receiving the greatest amount of water. This is likely the result of water entering the marsh from the south, and flowing north, through ditch D2 and ditch D3. Stake S1 had the lowest reading because it was placed away from any water sources, while stakes S2 and S3 were placed among water sources and stake S4 was placed approximately 15 meters from a water source. The highest reading, obtained near the pond, coincided with eroded banks and heavy *P. australis* growth in that area.

Table 5-19. Havens Point Tidal Inundation

| Stake | Marsh Placement | Tidal Inundation (centimeters) |
|---|---|---|
| S1 | Low | 10 |
| S2 | Middle-lower portion | 13 |
| S3 | Middle-upper portion | 18 |
| S4 | Upper | 14 |

### *Stormwater*

No stormwater discharge pipes were observed. Stormwater sheet flow onto the marsh is expected from the adjacent residential area, between Pine Edge Drive and Beach Boulevard and from the residential area east of an offshoot of Pine Edge Drive.

### *Water Quality*

Water quality samples were taken at various locations along three ditches (D1, D2 and D3) and one pond (P1). Water flows, water depth, ditch width, and substrate firmness increased in a northerly direction. Salinity and temperature remained constant across the marsh in a north/south direction, but varied from the upland to the lower marsh areas. Salinity in the pond and upper marsh was less than the salinity in the lower marsh and was inversely proportional to tidal inundation. Conversely, temperature increased from the lower marsh to the upper marsh. An increase in temperature may have been due to a decrease in ditch water depth. Water quality measurements could not be taken in several areas along ditch D3 because they were occluded with plants or a piece of wood. Trends in dissolved oxygen could not be analyzed due to instrument malfunction in the field.

Table 5-20. Havens Point Station Water Depth and Water Quality Measurements

| Sample Location | Station Location Characteristic | Station Water Depth (centimeters) | Temperature (ºC) | Salinity (ppt.) |
|---|---|---|---|---|
| D1A | Low marsh | 25 | 6.2 | 24.2 |
| D1B | | 20 | 5.3 | 24.7 |
| D2A | Lower middle marsh | 30 | 5.5 | 24.5 |
| D2B | | NR | 6.2 | 24.1 |
| D2C | | NR | 7 | 22.9 |
| D2D | | 10-15 | 6.7 | 24.0 |
| D3A | Upper middle marsh | 0.0 | NA | NA |
| D3B | | 15 | 10.4 | 23 |
| D3C | | 45 | 10.1 | 23.4 |
| D3D | | 5-7 | NA | NA |
| D3E | | 0.0 | NA | NA |
| P1 | Upper middle marsh, large pond | 10 | 9.7 | 22.2 |

NR-“not recorded” for a specified sample
NA- “not available” due to a small amount of water present
D = ditch P = pond
A, B, C and D = samples taken along a ditch

*Ecology*

Tidal Vegetation

A mix of salt marsh hay (*Spartina patens*) and the short form of smooth cordgrass (*Spartina alterniflora*) commonly covered the panels of land in between ditches; while the tall form of *S. alterniflora*, sea lavender (*Limonium carolinianum*) and marsh elder (*Iva frutescens*) were common along ditch edges. The common reed (*Phragmites australis*) dominated the upland border and surrounded the perimeter of a bell-shaped pond (approximately 60 x 38 meters) that was located between the upland and the terrestrial border of the marsh. *Phragmites australis* has also invaded the *S. patens/S. alterniflora* mix along the ditch draining the pond, and was present in the seaward border of the panels. The banks of the ditch draining the pond, along with several side ditches, were wet and highly eroded, with marsh grasses present in individual clumps. A berm bordering the seaward edge of the marsh allowed the existence of a second set of upland plants, such as *Baccharis halimifolia, I. frutescens, L. carolinianum, S. alterniflora, S. spicata* and some *P. australis*.

A white film was present on the surface of the mud near the roots of the *S. patens* and *S. alterniflora* (short form) mix, suggests the presence of bacteria or algae. Additionally, sea lettuce (*Ulva* spp.) was present at the shore.

Phragmites

The common reed (*Phragmites australis*) dominated the upland border and surrounded the perimeter of a bell-shaped pond (approximately 60 x 38 meters) that was located between the upland and the terrestrial border of the marsh. *Phragmites australis* has invaded the *S. patens/S. alterniflora* mix in middle marsh areas and along the ditch draining the pond. This plant was also present in the seaward border of the panels.

Upland Vegetation

The upland area is dominated by *P. australis*, while white pine (*Pinus strobus*), white oak (*Quercus alba*), red oak (*Q. rubra*), and eastern red cedar (*Juniperus virginiana*) trees comprised the terrestrial border.

Wildlife

Fish were present in all ditches, except those that had little or no water due to plant blockages. Ribbed mussels (*Geukensia demissa*) were present along the edge of several ditches in the southern part of the marsh. Songbirds were noted in the area where the marsh emptied into the cove and a flock of snow geese were seen flying over the marsh and landing in the cove. Geese and ducks likely frequent the large pond since a hunter’s blind was spotted opposite the pond entrance.

*Mosquito Habitat/History*

Ditching and Ditch Condition

Grid ditching of the marsh has resulted in two main ditches parallel to Seatuck Cove and eight shorter ditches perpendicular to the cove. Two perpendicular ditches flanking the parallel ditch closest to the shore allow water to enter the marsh from the south, and exit from the north. Several perpendicular ditches were partially or totally occluded with the tall form of *Spartina* and/or *Phragmites australis*. The area near station D3D was also occluded by a piece of wood. Tidal flow in these areas was restricted and water depth was minimal, ranging from zero inches to three inches. A soft muddy bottom (approximately 60 centimeters) was common in all ditches, with the exception of the northern-most perpendicular ditch. A hard, sandy bottom existed at the mouth of this ditch, while a hard muddy bottom (5 centimeters) existed along the rest of the ditch.

Pesticide Applications

Havens Point has not been subjected to larvicide or adulticide applications. OMWM techniques have not been implemented at this marsh.

### 5.10.6 Johns Neck Creek

*Selection Criteria and Current Condition*

Johns Neck is located on the south shore of the Long Island mainland, in the central portion of the Town of Brookhaven, within the Mastic-Shirley peninsula. The peninsula juts into Long Island’s South Shore Estuary Complex, dividing the Great South Bay (to the west) from Moriches Bay (to the east). The two bays are connected by Narrow Bay, a shallow, and one-half to one-mile wide section of the South Shore Estuary.

Johns Neck was selected as a PSA because of the major vector control problems in the marsh and surrounding area, and because it was chosen as a risk assessment site and one of the caged fish study sites.

### *Location, Size and Ownership*

Johns Neck is approximately 31 hectares (76 acres) in size and is divided into two separate areas by Johns Neck Creek, a tributary of Narrow Bay. The western portion of Johns Neck is approximately 16 hectares (40 acres) in size and is bounded by Unchachogue Creek to the west and Johns Neck Creek to the east. The eastern portion of Johns Neck is approximately 15 hectares (36 acres) in size and is bounded by Johns Neck Creek to the west and by freshwater wetlands and residential development to the east.

Johns Neck is a state-designated conservation area, managed by NYSDEC for conservation purposes and water fowl hunting. The western marsh was the focus of this study.

### *Topography and Waterbodies*

The entire Mastic Beach peninsula is situated within the Hydrogeologic Zone IV, as delineated in the Long Island 208 Study. This area is a portion of the south shore shallow flow system that discharges to Narrow Bay. Groundwater in this area primarily moves laterally toward the coastal waters, possibly with some degree of upward flow as the groundwater discharges to the bay.

Johns Neck vegetation is dominated mainly by *Spartina alterniflora* and *Distichlis spicata*. A large upland border of *Phragmites australis* and *Iva frutescens* exist on the eastern portions of the marsh.

One pond and six pannes were observed Johns Neck. The pond measures approximately 4 x 2 meters (13 x 6.5 feet) in size and panne sizes ranged from 5 x 1 meters (16 x 3 feet) to 8 x 18 meters (26 x 59 feet).

### *Land Use and Population Density*

Dense residential development borders the northern portion of the marsh. Freshwater wetlands exist along the eastern boundary of the marsh.

Population is 5,915 within one-half mile, and 19,525 within two miles. Predominant land use north of the site is single-family residential development on small lots.

### *Tidal Characteristics*

#### Tidal Range

Johns Neck is not tidally restricted. Based on tidal information for Mastic Beach, the mean tidal range for Johns Neck is approximately 15 centimeters. The spring tidal range is approximately 18 centimeters and the mean tide is six centimeters.

#### Tidal Inundation

In order to assess the amount of tidal inundation on the marsh surface in areas of high marsh, a tidal inundation study was completed during the lunar high tide in October 2004. Before the lunar high tide, stakes were placed in areas of standing water throughout on October 27th and inundation measurements were collected on October 28th.

Stake S1 and S2 were placed adjacent ditches amidst high marsh vegetation. Stake S1 received 12 cm of water and stake S2 received 11.5 cm of water. Stake S3 was placed in a panne surrounded by mixed high marsh and intertidal marsh vegetation. This panne received 31.5 cm of water. Stake S4 was placed in a pond located south of the panne. The pond received 14.5 cm of water. Stake S5 was placed in high marsh where inundation reached 18 cm. Stake S6 was placed in high marsh vegetation. This area received 13 cm of water.

Stakes S5 and S6 in the mid section of the marsh most likely receive inundation through spurs created off main ditches. The panne where stake S3 was placed received the most amount of inundation. This is likely due to the low topography of the surrounding area and the proximity to Unchachogue Creek.

Table 5-21. Johns Neck Tidal Inundation

| Stake | Marsh Placement | Tidal Inundation (centimeters) |
|---|---|---|
| S1 | High marsh | 12 |
| S2 | Adjacent to ditch | 11.5 |
| S3 | Panne | 31.5 |
| S4 | Pond | 14.5 |
| S5 | High marsh | 18 |
| S6 | High marsh | 13 |

### *Stormwater*

No stormwater discharge pipes were observed at Johns Neck.

### *Water Quality*

Water quality measurements were collected from the head, mouth, and mid-point sections of the tidal creek and two selected ditches (D1 and D2). Both ditches were analyzed at low tide.

Temperature, salinity, and dissolved oxygen increased with depth towards the mouth of ditch D1. Salinity was the lowest at the head of ditch D1 where *Phragmites australis* occluded the ditch. Temperature and dissolved oxygen also increased with depth towards the mouth of ditch D2. Salinity remained constant along ditch D2.

Table 5-22. Johns Neck Water Quality Data and Ditch Water Depth

| **Station** | **Sample Location Characteristics** | **Water Depth (centimeters)** | **Temp. (C)** | **Salinity (ppt.)** | **DO (mg/L)** |
|---|---|---|---|---|---|
| TC-A | *S. alterniflora* | >100 | 15.5 | 21.9 | 7.51 |
| TC-B | *S. alterniflora* | >100 | 16.0 | 21.6 | 7.54 |
| TC-C | *Phragmites*, steep bank | >100 | 16.7 | 21.6 | 7.82 |
| D1A | *S. alterniflora, D. spicata* | 35 | 16.8 | 21.5 | 5.45 |
| D1B | *Iva frutescens*, berm | 17 | 15.0 | 20.3 | 1.13 |
| D1C | *S. alterniflora* | 4 | 14.5 | 7.2 | 2.81 |
| D2A | *S. alterniflora, D. spicata* | 44 | 16.4 | 22.0 | 6.87 |
| D2B | *Iva frutescens*, berm | 32 | 15.6 | 22.8 | 4.35 |
| D2C | *Phragmites* | 6 | 14.4 | 21.5 | 4.31 |

Note: Samples collected on 10/13/04; 1:03 p.m. low tide
D = ditch TC = tidal creek

### *Ecology*

#### Tidal Vegetation

The vegetation at Johns Neck consists predominantly of *Spartina alterniflora* mixed with *Distichlis spicata*. *Spartina alterniflora* becomes the dominant vegetation along the western portion of ditches and along the tidal creek. *Distichlis spicata, S. patens,* and *Iva frutescens* dominate the high marsh vegetation. *Iva frutescens* is more abundant along the eastern portions of the ditches and among ditch berms.

#### Phragmites

A large dense stand of *Phragmites australis* exists along the eastern boundary of the marsh where freshwater wetlands are present.

Wildlife

Few to moderate numbers of Atlantic silverside (*Menidia menidia*) were observed in the ditches during high tide. The pond and pannes contained few numbers of fish during the lunar high tide. One of the pannes also contained an abundant number of grass shrimp (*Palaemonetes pugio*).

*Mosquito Habitat/History*

Ditching and Ditch Condition

Johns Neck has been subject to ditching throughout the entire marsh. Parallel ditches run from east to west and are spaced approximately 60 meters (200 feet) apart. Perpendicular spurs and an upland perimeter ditch had also been constructed.

Two ditches (D1 and D2) were analyzed for general ditch characterization. These ditches have clear connections to Unchachogue Creek and terminate in *Phragmites australis*. The ditches at Johns Neck have muddy substrates.

Adjacent vegetation along the D1 consists mainly of *S. alterniflora.* Berms are present on the south and north side of D1 along the south side of D2. *Iva frutescens* is the dominant vegetation on the berms.

Pesticide Applications

Aerial larvicide applications are performed throughout the marsh during the mosquito-breeding season. Ground adulticide applications are applied near the marsh in the nearby residential areas. No OMWM techniques have been installed on this marsh.

### 5.10.7 Stillman Creek and Namkee Creek

*Selection Criteria and Current Condition*

The wetlands at Stillman Creek and Namkee Creek were selected as PSAs because they are south shore fringing marshes of manageable size that are part of a diverse complex, and are sites of vector control problems.

*Location, Size and Ownership*

Stillman Creek and Namkee Creek are located on the south shore of the Long Island. Stillman Creek, located within the western section of the Town of Brookhaven, drains into Patchogue Bay. Namkee Creek, located 350 meters (1,150 feet) west of Stillman Creek, is located within the Town of Islip and empties into Great South Bay.

Stillman Creek is approximately 7.6 hectares (19 acres) in size and Namkee Creek is approximately 10.5 hectares (26 acres). Both marshes are bounded to the east and west by residential development. Stillman Creek and Namkee Creek are state-owned tidal wetlands that are managed by NYSDEC for conservation purposes and water fowl hunting.

### *Topography and Waterbodies*

Stillman Creek and Namkee Creek are situated within Hydrogeologic Zone VI, as delineated in the Long Island 208 Study. This south shore zone is a ‘surface water impact area,’ where groundwater discharges to Moriches Bay and the eastern portion of Great South Bay. Any contaminants present in the groundwater can have a major impact on surface waters, as flushing rates in this part of the Bay are low.

The marshes at Stillman Creek and Namkee Creek are similar in topography in that they both have a large dense stand of *Phragmites australis* that dominates the northern portion of the marshes. A mixture of *P. australis* and *Baccharis halimifolia* border the southernmost portions of both marshes. Both sites have been grid ditched with extensive grid networks in the southern portions of the marshes.

Stillman Creek divides the Stillman Creek marsh in half laterally. The mouth of the creek is approximately three meters (9.8 feet) wide at high tide, allowing a clear connection to Great South Bay. Several pannes and ponds are located in the center portion of the marsh. The maximum depth of ponds measured 20 cm (8 inches) deep and the maximum size was 20 x 25 meters (65 x 80 feet) wide.

Namkee Creek runs along the eastern boundary of the Namkee Creek marsh. The creek empties into the bay via an underground drainage pipe. Namkee Creek also contains numerous pannes and ponds throughout the low-lying areas of the marsh. The depths of the ponds range from 11 to 22 cm (4 x 9 inches) deep, and were as large as 15 x 24 meters (50 x 80 feet).

### *Land Use and Population Density*

Predominant land use near the two sites is residential development. The population is 3,047 within one-half mile of Stillman Creek and 27,000 within two miles. The population is 3,000 within one-half mile of Namkee Creek, and 25,000 within two miles.

### *Tidal Characteristics*

#### Tidal Range

Stillman Creek has an unobstructed connection to the bay and, therefore, is not tidally restricted. Namkee Creek is tidally restricted due to the underground drainage pipe that empties into Great South Bay. Based on tidal location information at Patchogue, the mean tidal range for this area is approximately 20 cm (0.7 feet). The spring tidal range is approximately 25 cm (0.8 feet) and the mean tide is 10 cm (0.3 feet).

#### Tidal Inundation

In order to assess the amount of tidal inundation on the marsh surface, a tidal inundation study was completed during the full moon high tide in October 2004. Before the lunar high tide, stakes were placed in areas of standing water throughout the high marsh.

Seven stakes were placed throughout Stillman Creek on October 27th and inundation measurements were taken on October 28th. Two stakes were placed in ponds, two were placed in pannes and the rest were placed in the high marsh.

Stake S1 was placed amidst high marsh vegetation in the southeast section of the marsh. This area received 10 cm of inundation during the lunar high tide. Stake S2 was placed in the high marsh near the tidal creek. This area was surrounded by *Spartina patens* and received a maximum of 14 cm of water. Stake S3 was placed in a pond adjacent a ditch. This location is surrounded by mixed intertidal and high marsh vegetation. Tidal inundation in this pond measured 12 cm. Stake S4, placed in mixed vegetation adjacent to the tidal creek received 18 cm of water. Stake S5 was placed in a panne just north of the southern berm, and west of S1. Stake S5 received 29 cm of water, significantly higher than S1. This increase may be due to the increase of the height of the berm along the southern boundary of the marsh. This is also evident by the large amount of dead eel grass noted in the ditch adjacent to S5. Stake S6 was placed in a pond surrounded by mixed vegetation east of the tidal creek. This area received 13 cm of water, likely fed by an adjacent ditch, which is directly connected to the tidal creek. Stake S7 was placed in a panne east of the tidal creek surrounded by high marsh vegetation. This area received 9 cm of water. The elevation of this area was slightly higher, which may reason for less amount of inundation.

Table 5-23. Stillman Creek Tidal Inundation

| Stake | Marsh Placement | Tidal Inundation (centimeters) |
|---|---|---|
| S1 | High marsh | 10 |
| S2 | High marsh | 14 |
| S3 | Pond | 12 |
| S4 | High marsh | 18 |
| S5 | Panne | 29 |
| S6 | Pond | 13 |
| S7 | Panne | 9 |

Seven stakes were placed throughout Namkee Creek on October 27th and inundation measurements were collected on October 28th. Stake S1 was placed adjacent to a ditch in high marsh vegetation. This area received 13 cm of water during the lunar high tide. Stake S2 was placed amidst high marsh *Phragmites australis*. This area received 20 cm of inundation. Stake S3 was placed in panne adjacent to Ditch 2. This panne received 13 cm of water. Stake S4 was placed on the edge of a pond surrounded by mixed vegetation. This area received 21 cm of water. Stake S5 was placed in a pond surrounded by intertidal vegetation. This area received the most amount of inundation with 27.5 cm of water. This is likely due to the low topography and extensive grid ditches in the area. Stake S6 was placed in a pond surrounded by mixed vegetation east of S5. This area received 19 cm of water. Stake S7 was placed in the northernmost section of the marsh in a pond surrounded by high marsh vegetation and *Phragmites*. This area received 9 cm of water. The elevation of the marsh is slightly higher towards in this area, which may be the result of less inundation. With the exception of stake S5, the stakes positioned closest to the tidal creek received more inundation. Stake S6 received similar inundation amounts as those near the tidal creek because of a natural ditch extending from the creek into the area of stake S6.

Table 5-24. Namkee Creek Tidal Inundation

| Stake | Marsh Placement | Tidal Inundation (centimeters) |
|---|---|---|
| S1 | Adjacent to ditch | 13 |
| S2 | High marsh | 20 |
| S3 | Panne | 13 |
| S4 | Edge of pond | 21 |
| S5 | Pond | 27.5 |
| S6 | Panne | 19 |
| S7 | Pond | 9 |

### *Stormwater*

No stormwater discharge pipes were observed at Stillman Creek or Namkee Creek. The creeks comprise minor drainage basins, between the larger Browns River (to the west) and Patchogue River (to the east) drainage basins. These very small, short streams only drain the immediate vicinity of the wetlands.

### *Water Quality*

Water quality measurements were taken along three ditches (D1, D2, and D3) at Stillman Creek during ebb tide. Temperature increased towards the head of ditches D1 and D2. Salinity measurements varied but were highest at the head of ditch D1. Salinity measurements along ditch D2 were lowest at the head of the ditch. Dissolved oxygen decreased with higher temperature and salinity in ditches D1 and D2. Temperature recordings were highest along ditch D3. Temperature, salinity, and dissolved oxygen were similar along ditch D3.

Water quality measurements were collected along two ditches (D1 and D2) at Namkee Creek. Both ditches varied in all parameters. Higher temperature and salinity corresponded with greater ditch depth. Dissolved oxygen varied with depth along both ditches. Salinity varied along ditch D1 and temperature decreased slightly toward the mouth. This is mostly likely because the mouth of ditch D1 was taken at the junction of Namkee Creek, which is tidally restricted. Higher salinity readings at the head of ditch D1 may be the result of an adjoining ditch, which may receive sheet overflow from the bay.

Table 5-25. Stillman Creek Water Quality Data and Ditch Water Depth

| **Station** | **Sample Location Characteristics** | **Water Depth (centimeters)** | **Temp. (C)** | **Salinity (ppt.)** | **DO (mg/L)** |
|---|---|---|---|---|---|
| TC-A | *Ammophila breviligulata* | 16 | 9.8 | 15 | 4.65 |
| TC-B | *S. patens, Phragmites* | 29 | 10 | 5.8 | 4.38 |
| TC-C | Upland vegetation | 38 | 10.9 | 0.1 | 5.04 |
| D1A | *S. alterniflora, S. patens* | - | 13.5 | 2.4 | 9.96 |
| D1B | *S. patens, Phragmites, Iva frutescens* | - | 16.1 | 0.2 | 3.15 |
| D1C | *S. alterniflora, S. patens* | - | 16.7 | 4.8 | 1.02 |
| D2A | *S. alterniflora* | - | 17 | 17.5 | 1.34 |
| D2B | *S. alterniflora* | - | 17.8 | 18 | 0.40 |
| D2C | *S. alterniflora* | - | 20 | 15.5 | 0.74 |
| D3A | *S. patens, Phragmites* | - | 21.9 | 9.2 | 2.6 |
| D3B | *S. alterniflora, S. patens* | - | 22.1 | 9.9 | 3.01 |

Note: Samples collected on 10/7/04, 2 ½ hours before low tide
D = ditch TC = tidal creek

Table 5-26. Namkee Creek Water Quality Data and Ditch Water Depth

| **Station** | **Sample Location Characteristics** | **Water Depth (centimeters)** | **Temp. (C)** | **Salinity (ppt.)** | **DO (mg/L)** |
|---|---|---|---|---|---|
| TC-A | *Phragmites, Baccharis halimifolia, Toxicodendron radicans* | >100 | 9.3 | 8.8 | 2.97 |
| TC-B | *Phragmites australis* | 15 | 9.1 | 2.6 | 3.60 |
| TC-C | *Phragmites australis* | 8 | 10.4 | 0.2 | 1.34 |
| D1A | *Phragmites australis* | 15 | 15.1 | 9.3 | 3.9 |
| D1B | *Phragmites australis, Distichlis spicata* | 17 | 16 | 13.6 | 7.25 |
| D1C | *Phragmites australis* | 24 | 17.2 | 15.4 | 5.58 |
| D2A | *Phragmites, B. halimifolia, T. radicans* | 20 | 16.1 | 14.5 | 14.77 |
| D2B | *Phragmites australis* | 19 | 14.4 | 10.9 | 0.32 |
| D2C | *Phragmites australis* | 14 | 13.8 | 10.8 | 2.24 |

Note: Samples collected on 10/12/04, during low tide (4:30 p.m.)
D = ditch TC = tidal creek

### *Ecology*

#### Tidal Vegetation

*Spartina alterniflora* is the dominant vegetation along the ditches and in a few low lying areas at Stillman Creek. The mid portions of the marsh, generally near ponds and pannes, are dominated by a mix of high marsh and intertidal vegetation. Clumps of *S. alterniflora* are present among ponds and pannes. *Distichlis spicata* and *S. patens* dominate the high marsh, tidal creek edges and perimeter of the marsh at Stillman Creek. *Iva frutescens, Baccharis halimifolia, Salicornia,* and *Phragmites australis* are also located throughout the high marsh. *Iva, Baccharis, Phragmites,* and *Toxicodendron radicans* (poison ivy) form a southern high marsh border.

Only a few small areas throughout the Namkee Creek marsh are dominated by intertidal vegetation. *S. alterniflora* is mainly mixed with high marsh vegetation, or in clumps among ponds and pannes. High marsh areas at Namkee Creek are dominated by large stands of *Phragmites australis*. *S. patens, D. spicata, Scirpus pungens, Pluchea purpurascens* and *Salicornia* are mixed with intertidal vegetation in the mid to lower section of the marsh.

#### Phragmites

An extensive amount of *Phragmites australis* is located in the upper portion and southern boundary of both Stillman Creek and Namkee Creek. *P. australis* is also abundant along the ditches and the west and eastern boundaries at Namkee Creek.

#### Wildlife

Few fish were observed in the ditches at Stillman Creek. Species of fish caught were mummichogs (*Fundulus heteroclitus*) and rainwater killifish (*Lucania parva*). A great blue heron (*Ardea herodias*), great white egret (*Casmerodius albus*) and mallards (*Anas Platyrhynchos*) were observed at Stillman Creek.

Mummichogs and rainwater killifish were moderately abundant in the ditches, pannes and ponds at Namkee Creek.

### *Mosquito Habitat/History*

#### Ditching and Ditch Condition

Stillman Creek and Namkee Creek have an extensive network of grid ditches throughout each marsh. Ditch spacing ranges from approximately 15 to 60 meters (50 to 200 feet) and are perpendicular to the adjacent tidal creeks.

Three ditches (D1, D2, and D3) at Stillman Creek were analyzed for general ditch characterization. The ditches have a soft muddy substrate and berms were absent from ditch edges. Adjacent vegetation consists mainly of *S. alterniflora*; however, ditches D1 and D3 had small sections of high marsh vegetation consisting of *Phragmites australis, Iva frutescens,* and *S. patens*.

Two ditches (D1 and D2) were analyzed for general ditch characterization at Namkee Creek. The ditches had a muddy substrate, with an increasing amount of sand towards the west. High marsh is the dominant vegetation adjacent to the ditches, mainly consisting of *Phragmites australis, D. spicata, Althea officinalis, Baccharis halimifolia,* and *Toxicodendron radicans.* Abundant amounts of fish were observed during high tide at the mid-length portion of ditch D1. None were noted at this location during low tide.

#### Pesticide Applications

Both sites receive aerial larvicide applications. No OMWM techniques have been implemented at either site.

### 5.10.8 Pepperidge Hall

*Selection Criteria and Current Condition*

The Pepperidge Hall State Tidal Wetland was chosen as a PSA because it is a south shore fringing marsh, with vector control problems, that is located adjacent to a residential area. Although the vegetation is relatively undisturbed, several berms limit tidal circulation into and out of the marsh. The County has suggested that the installation of fish reservoirs and spurs may limit mosquito breeding.

*Location, Size, and Ownership*

The Pepperidge Hall State Tidal Wetland is owned and managed by NYSDEC. It is located in the town of Oakdale, south of Montauk Highway and east of Vanderbilt Boulevard.

The wetland is approximately 22.0 hectares. Approximately 6.0 hectares of the total was studied. The site is bordered to the north by Blue Point Road, which also serves as an access road, and by Belvedere Drive, to the east.

*Topography and Waterbodies*

The Pepperidge Hall wetland is situated on the border of Hydrogeologic Zones VI and VII, as delineated in the Long Island 208 Study. This south shore Zone VI is a 'surface water impact area,' where groundwater discharges to Moriches Bay and the eastern portion of Great South Bay. Any contaminants present in the groundwater can have a major impact on surface waters in this area, as flushing rates in this part of the Bay are low. Zone VII is a south shore shallow flow systems, where groundwater generally flows laterally and can affect marine water quality.

A large tidal creek flowed along the northeastern edge of the wetland complex, while its southern shore was exposed to a substantial fetch across the Great South Bay. A small pond (<0.2 hectares) was found in the southwestern portion of the complex and a 0.8-hectare tidal pond connected to the tidal creek. Given the size of the tidal creek and the channel going into the larger pond, good tidal exchange in and out of the pond is highly possible. The tidal creek along the eastern edge of the wetland complex connected to a series of man-made lagoons located within residential developments.

There were five pannes in the study area, two in the low marsh, two in the middle marsh and one in the upper marsh. Three of the five pannes were located adjacent to an area dominated by *Phragmites australis*.

A substantial berm was located adjacent to the tidal creek along the northeastern edge of the wetland. The berm obstructed tidal flow into and out of all ditches along the northeastern segment of the marsh. Similarly, tidal flow was restricted along the western portion of the marsh by a berm running through the middle of the marsh, in a southeasterly direction.

### *Land Use and Population Density*

Land use surrounding the Pepperidge Hall State Tidal Wetland was completely residential. Population density within ½ mile of the wetland is 2,375 and 21,331 within two miles of the wetland. Houses, situated on 0.25 acre and 0.5 acre plots, lined Belvedere Drive and Blue Point Roads and bordered the study site to the northeast.

### *Tidal Characteristics*

#### Tidal Range

The mean tidal range (MHW–MLW) was 18 centimeters (0.6 feet) and the mean spring tidal range (MHHW-MLLW) was 21 centimeters (0.7 feet) (as measured at the Great River, Great South Bay).

#### Tidal Inundation

Tidal inundation measurements are pending.

### *Stormwater*

No stormwater discharge pipes were observed in the study area.

### *Water Quality*

Temperature increased from the low marsh to the high marsh in ditch 2 (D2), but was constant along ditches D3 and D4. Salinity increased toward the upper marsh in all three ditches, with salinity being slightly higher in ditch D2. The slightly higher temperature and salinity readings in ditch D2 were likely due to this ditch being located closer to a tidal pool, than ditches D3 and D4. Dissolved oxygen decreased toward the upper marsh in all ditches, with readings, again, being slightly higher in ditch D2. The trend in dissolved oxygen correlated with the trends displayed by the temperature and salinity readings (i.e. dissolved oxygen decreases as temperature and salinity increase). Temperature and salinity readings were highest and dissolved oxygen readings were lowest in salt panne P1, as is typical of salt pannes. Water quality measurements were not recorded for samples taken at stations D2C (middle marsh), D4E (upper marsh), and P2 (upper marsh) (Table 5-27).

Table 5-27. Pepperidge Hall-Water Quality Measurements

| **Station** | **Station Location Characteristics** | **Temperature (ºC)** | **Salinity (ppt.)** | **Dissolved Oxygen (mg/L)** |
|---|---|---|---|---|
| D1A | Low marsh, inlet to ditch around pond | 17.6 | 20.4 | 13.1 |
| D1B | Low marsh, ditch around pond | 16.7 | 20.5 | 11.7 |
| D2A | Low marsh | 16.5 | 20.6 | 12.8 |
| D2B | | 17.0 | 20.6 | 9.8 |
| D2C | Middle marsh | NR | NR | NR |
| D3A | Low marsh | 17.0 | 20.2 | 11.3 |
| D3B | | 17.7 | 19.5 | 11.2 |
| D3C | Middle marsh | 17.2 | 18.9 | 9.8 |
| D3D | | 17.0 | 18.1 | 9.4 |
| D3E | Upper marsh | 17.4 | 17.3 | 10.0 |
| D4A | Low marsh | 17.6 | 19.9 | 11.6 |
| D4B | | 17.5 | 19.1 | 12.6 |
| D4C | Middle marsh | 16.6 | 16.6 | 10.9 |
| D4D | | 19.0 | 26.4 | 9.6 |
| D4E | Upper marsh | NR | NR | NR |
| P1 | | 19.0 | 18.3 | 13.5 |
| P2 | | NR | NR | NR |

Notes: D = ditch P = panne NR = not recorded
A, B, C, D and E = samples taken along ditch

### *Ecology*

#### Tidal Vegetation

*Spartina alterniflora* dominated the low marsh, while a mix of *S. alterniflora* (short form) and *S. patens* covered the middle and upper marsh. However, a narrow band of this mix surrounded the tidal pond. Clear vegetation patterns were evident along ditch edges where the tall form of *Spartina alterniflora* dominated. *Iva frutescens* was present in the transition zone from the low to middle marsh, along the edges of ditches D2 and D3, but was conspicuously absent in the same area along ditch D3.

#### Phragmites

The common reed, *P. australis*, formed an almost continuous border around approximately 75 percent of the study site, with a break of trees and *Spartina alterniflora* located in the northwestern portion of the border. *Phragmites australis* did not border the edge of the 0.8-hectare tidal pond or the main trench draining the pond.

#### Upland Vegetation

Approximately 90 percent of the upland was dominated by *P. australis*, with the remaining 10 percent being covered by trees in the northwest corner of the study site. Marsh elder (*Iva frutescens*), mixed with *P. australis*, was present in the northeastern corner of the study area, near station D.

#### Wildlife

Fish were present through out the site, declining in number toward the upland. A crab (possibly the green crab, *Carcinus maenas*) was spotted in the low marsh near station D3B. Amphipods were abundant in the large panne located west of stations D4D.

### *Mosquito Habitat/History*

#### Ditching and Ditch Condition

The complex was extensively ditched, with virtually all the ditches on the eastern side of the marsh discharging either directly into the pond or into two large ditches that drained into the pond. The ditches were parallel to each other and spaced at approximately 30-meter intervals. Tidal circulation into the parallel ditches was good, primarily due to the presence of two large ditches running in a southeasterly and northwesterly direction from the pond. Water circulation from the pond extended into these two main ditches, and into the tributary ditches. Better circulation could be achieved if the berms that bordered the eastern and western edges of the marsh were removed.

Water depth was greatest along ditch D4 and lowest along ditch D2. The difference was probably caused by a difference in ditch length, as the upper portion of ditch D2 is overgrown with *P. australis*. Water depth was constant along each individual ditch. The substrate of ditch D2 was approximately 45 centimeters of mud, while approximately 60 centimeters of mud lined ditch D3.

#### Pesticide Applications

The Pepperidge Hall State Tidal Wetland has received applications of larvicide and adulticide. OMWM techniques have not been implemented at this marsh.

### 5.10.9 Pickman-Remmer

*Selection Criteria and Current Condition*

The Pickman-Remmer State Tidal Wetland was selected as a PSA because a canal has divided it into two distinct segments. The eastern segment is impounded by a dredge spoil berm, whereas the western segment retains good tidal flow. The vegetation pattern clearly reflects the differences in tidal exchange. The eastern segment is severely degraded with the common reed, *Phragmites australis,* as the dominant plant species, while the western segment retains a plant community more characteristic of healthy tidal marshes.

In the eastern segment, the large size of a berm bordering the marsh and the small size of three existing culverts do not permit sufficient tidal exchange to support the plant species characteristic of a healthy northeastern salt marsh. This is supported by the fact that the entire length of the marsh, in between the first and third culverts (approximately 273 meters) is covered by *P. australis*. *Phragmites australis* has spread since the last aerial image of the marsh was taken in 2001.

The Pickman-Remmer State Tidal Wetland supports mosquito populations, requiring control by the County. The eastern marsh is a prime candidate for tidal flow restoration. The following discussion highlights observed differences between the two marsh segments.

*Location, Size, and Ownership*

The Pickman-Remmer State Tidal Wetland is in the town of Oakdale and is owned by NYSDEC. It is located south of Montauk Highway and Idle Hour Boulevard. The Grand Canal divides the wetland into two separate segments. The western segment can be accessed via Central Boulevard and is approximately 16 hectares in size. Approximately 325 meters of the marsh border were examined. The southwestern portion of the eastern segment can be accessed by Riverview Court and is approximately 4.6 hectares in size. Approximately 1.2 hectares of this marsh segment were studied.

*Topography and Waterbodies*

The Pickman-Remmer wetland is situated on the border of Hydrogeologic Zones VI and VII, as delineated in the Long Island 208 Study. This south shore Zone VI is a surface water impact area, where groundwater discharges to Moriches Bay and the eastern portion of Great South Bay.

Any contaminants present in the groundwater can have a major impact on surface waters in this area, as flushing rates in this part of the Bay are low. Zone VII is a south shore shallow flow systems, where groundwater generally flows laterally and can affect marine water quality.

Eastern Segment

A dredge-spoil berm (approximately 1.5 meters high on the canal side and 60 centimeters on the marsh side) lined the east side of the canal and was composed of hard, sandy soil. A ditch separated the marsh from the berm. The small amount of marsh interior that was accessible contained grass clumps surrounded by mud.

A tidal creek (approximately 350 meters long) divided this marsh segment in half. The head of the creek was located in the southern part of the marsh, north of the intersection of Shore Drive and Fern Place, while the mouth of the creek was located across from the first section of houses lining the canal, and was blocked by the berm. A breach in the berm at the first culvert, along with culverts two and three, and the ditch behind the berm, were the only points at which the marsh directly connected to the canal.

Western Segment

The marsh surface in the western segment of the marsh was wet and hummocky. The ground had boggy characteristics when jumped on.

### *Land Use and Population Density*

Land use within the vicinity of the Pickman-Remmer State Tidal Wetland was heavy residential development. The population within ½ mile of the marsh is approximately 2,000 people and 20,000 within two miles. Blocks of houses, situated on a quarter-acre and half-acre plots, lined the west bank of the canal and comprised the northern border of the western segment.

### *Tidal Characteristics*

Tidal Range

The mean tidal range (MHW–MLW) is 21 centimeters (0.7 feet) and the mean spring tidal range (MHHW-MLLW) is 24 centimeters (0.8 feet) (as measured at Connetquot River, Great South Bay).

Eastern Segment Tidal Inundation

Two stakes were placed in the eastern marsh segment to measure tidal inundation on 5/9/2005 and retrieved the following day. Stake S1 was placed in a salt panne amongst the *Phragmites* and stake S2 at the junction of two ditches near the ditch mouth. The stakes were placed the day after the monthly full moon. Stake S1 was inundated with 19 centimeters of tidal water and stake S2 with 18 centimeters. The portion of the marsh near the berm is inundated at full moon high tide. Portions of this further east and upland were inaccessible due to the dense *Phragmites*.

Western Segment Tidal Inundation

Stakes measuring tidal inundation (stakes S3, S4, and S2) in the western segment were placed on 5/9/2005 and retrieved the following day. Stake S3 and S4 were placed in the high marsh near the upland. Stake S5 was located at the head of a tributary ditch in the high marsh midway between the tidal channel and the upland. The stakes revealed that at least the lower (western) portion of the marsh is inundated at full moon high tide (Table 5-28).

Table 5-28. Pickman-Remmer Tidal Inundation (Western Segment)

| Stake | Marsh Placement | Tidal Inundation (centimeters) |
|---|---|---|
| S1 | Eastern segment – High marsh | 19 |
| S2 | Eastern segment – High marsh | 19 |
| S3 | Western segment – High marsh | 27 |
| S4 | Western segment – High marsh/upland | 8 |
| S5 | Western segment – High marsh | 19 |

*Stormwater*

Eastern Segment

Three culverts (approximately 45 centimeters in diameter) penetrated the berm to allow drainage of the marsh. Culvert C1, located directly across from the small marsh on the opposite side of the canal, was covered with sand and completely blocked with sediment. Culvert C2 was partially blocked with sediment and pieces of the common reed, *Phragmites australis*, while culvert C3 had water flowing through it. The 2001 aerial photograph of the site depicts an indentation in the berm edge, north of culvert C2, indicating the existence of a fourth culvert. However, a fourth culvert was not observed.

Western Segment

Stormwater discharge pipes were not observed in the western segment.

### *Water Quality*

#### Eastern Segment

Temperature, salinity, and dissolved oxygen readings were highest near culvert C1. Otherwise, temperature readings were similar, while salinity at culvert C1 also differed from the rest of the sampling stations. It was sandy and hard versus muddy (60 centimeters deep). The area near culvert C1 was the only location where tidal exchange occurred freely, due to a breach in the berm. Additionally, dissolved oxygen was lowest in the canal, near culvert C3 (Table 5-29).

Table 5-29. Pickman-Remmer Water Quality Measurements (Eastern Segment)

| **Station** | **Station Location Characteristic** | **Temperature (°C)** | **Salinity (ppt.)** | **Dissolved Oxygen (mg/L)** |
|---|---|---|---|---|
| D1A* | Adjacent to berm, near C1 | 5.8 | 18.9 | 8.2 |
| D1B | Behind berm, near D1A | 4.9 | 18.1 | 8.4 |
| D2A | Behind berm, C2 | 5.0 | 16.9 | 5.5 |
| D3A | Behind berm, in D4 | 5.0 | 17.0 | 6.7 |
| D4A* | In canal, in front of C3 | 5.3 | 17.6 | 3.1 |

Note: D = ditch C = culvert
A and B = samples taken along ditch
* = samples taken in main canal

#### Western Segment

Two ditches (D1 and D2) were sampled for temperature, salinity and dissolved oxygen in the low marsh, middle marsh, and upper marsh areas. Temperature and salinity displayed little variation throughout the marsh (Table 5-30). Water quality measurements varied most in the middle marsh samples, but were similar in the upper and low marsh samples. The variation among middle marsh samples was likely caused by a difference in ditch length. Dissolved oxygen readings varied most in the low marsh, from 11.7 mg/L to 3.2 mg/L. Readings for dissolved oxygen were constant in the middle and upper marsh samples. Overall, better tidal circulation in the western segment of the marsh, may have accounted for salinity being higher in the western segment versus the eastern marsh segment. Likewise, higher temperature in the western segment, versus the eastern segment, may account for lower dissolved oxygen there.

Table 5-30. Pickman-Remmer Water Quality Measurements (Western Segment)

| **Station** | **Station Location Characteristic** | **Ditch Water Depth (centimeters)** | **Temperature (ºC)** | **Salinity (ppt.)** | **Dissolved Oxygen (mg/L)** |
|---|---|---|---|---|---|
| D1A* | Low Marsh | NR | 6.8 | 20.0 | 11.7 |
| D1B | Middle Marsh | 30 | 6.6 | 20.2 | 8.9 |
| D1C | Middle Marsh | 5 | 6.3 | 18.9 | 6.5 |
| D1D | Upper Marsh | 17 | 6.2 | 19.1 | 6.8 |
| D2A* | Low Marsh | 10 | 7.6 | 20.5 | 3.2 |
| D2B | Middle Marsh | 45 | 6.5 | 19.2 | 8.9 |

Note: NR- "not recorded" for a specified sample
D = ditch A, B, C and D = samples taken along ditch
* = samples taken in tidal creek at mouth of ditch

### *Ecology*

#### Eastern Segment Tidal Vegetation

Typical tidal vegetation was lacking in all areas of the marsh, with the exception of two triangular panels *S. patens* near culvert C3 and a band of *S. patens* present south of where sampling station D3A. The tall form of *S. alterniflora* was growing along the berm/canal interface. It is important to note that the vegetation pattern reflected in the 2001 aerial photographs has since changed.

#### Western Segment Tidal Vegetation

Tidal vegetation in the western segment consisted of the tall form of *S. alterniflora* growing along the edges of ditches and the canal, while clumps of *S. patens*, mixed with *D. spicata* and the short form of *S. alterniflora*, covered the middle and upper marsh.

#### Phragmites Eastern Segment

The presence of the common reed, *Phragmites australis*, was so overwhelming that at first glance, the site appeared monospecific. This plant dominated the entire length of the marsh, between culverts C1 and C3 (approximately 273 meters.). *Spartina patens* persisted in two small areas. Reeds approximately three meters high lined the marsh perimeter, while plants, approximately one meter high covered the marsh interior.

#### Phragmites Western Segment

*Phragmites australis* was growing along the terrestrial border, following the curve of Riverview Court and tapering off toward the eastern edge of the marsh. *P. australis* was also growing along the banks of ditches in the upper and middle marsh areas. A corridor of *P. australis*, which extended from upper marsh to the middle marsh, was present west of ditch D1.

#### Upland Vegetation Eastern Segment

The berm supported sea myrtle (*Baccharis halmifolia*), marsh elder (*Iva frutescens*) switch grass (*Pancium virgatum*), white oak (*Quercus alba*), red oak (*Q. rubra*), scrub oak (*Q. ilcifolia*) white pine (*Pinus strobus*), and eastern red cedar (*Juniperus virginiana*). The upland area is dominated by *P. australis*, while *Pinus strobus*, *Quercus alba*, and *Juniperus virginiana* comprised the terrestrial border. A stand of trees (approximately 122 x 43 meters.), including *Pinus strobus* and *Quercus alba*, were found west of the creek.

#### Upland Vegetation Western Segment

A thin line of *Quercus alba* and *Q. rubra*, along with some willow trees (*Salix* spp.) bordered Riverview Court. *Baccharis halmifolia* bushes were mixed with *P. australis* along the marsh border and *Iva frutescens* was mixed with *P. australis* along ditch edges. *Iva frutescens* was also present in a thin band west of ditch D1.

#### Wildlife

The only wildlife observed in the eastern segment was a muskrat near the location of station D2A. Fish and mallard ducks were present in the canal that bordered the western segment and songbirds were present in the trees of the upland border.

### *Mosquito Habitat/History*

#### Ditching and Ditch Condition

Ditches west of the creek were parallel to each other and were angled toward the canal. Ditches east of the creek were also parallel to each other, but were angled toward the creek. All of these ditches led to a main ditch running the length of the berm. Several areas along the main ditch were highly eroded or dry. The few angled ditches that were visible from the berm had highly eroded banks were irregular in width and contained sizeable quantities of *P. australis* detritus.

Ditches were parallel to each other and perpendicular to the canal. The mouths of these ditches have been eroded to shelves and contained dead plant matter. Ditch D2 was clogged with a mix of *S. patens* and *S. alterniflora* (short form). No water movement and no fish were present in this ditch.

Pesticide Applications

The marsh has received larvicide and adulticide applications. OMWM techniques have not been implemented at this site.

### 5.10.10 Pine Neck

*Selection Criteria and Current Condition*

The Pine Neck wetland was selected as a PSA because it is a south shore fringing marsh with few vector control problems and a healthy vegetation pattern. The wetland appears to be in transition. *Phragmites australis* surrounds the wetland, ditches are filling, and numerous cedars have died. Minimal ditch maintenance may lead to changes in the vegetation pattern and possibly mosquito breeding.

*Location, Size, and Ownership*

The Pine Neck wetland, in the Town of Southampton, is owned and managed by the NYSDEC. The wetland is located south of Montauk Highway, between Pine Neck Point and the mouth of Weesuck Creek, bordering Shinnecock Bay. The entire tidal wetland complex is less than six hectares in size. The study area can be accessed via Widgeon Lane and measures approximately 180 x 270 meters.

*Topography and Waterbodies*

The Pine Neck wetland is situated within Hydrogeologic Zones V, which includes the western south fork as delineated in the Long Island 208 Study. Groundwater from the Pine Neck wetland discharges to Shinnecock Bay, where flushing rates are high.

The southern edge of the marsh has been exposed to a several mile southwesterly fetch that could regularly alter the shape of the shoreline. South of Widgeon Lane, in the northeastern corner of the site, seven similarly sized pools (all approximately 3.0 to 4.5 meters wide) were present among numerous dead shrub and tree stumps. Several small pools (all approximately 1 meter wide) were interspersed throughout the middle marsh in the areas near ditches D1 and D2. A small salt panne, surrounded by *Spartina patens* and *Phragmites australis* growth, was present in the upper marsh.

*Phragmites australis* and upland forest surrounded the wetland on all sides, except the seaward edge. The tree line and *P. australis* growth were thinnest in the area between Widgeon Lane and the head of ditch D1. Two areas of dead trees were adjacent to the *P. australis* growth on the eastern edge of the site and extended north toward the head of ditch D1. *Iva frutescens* and *Baccharis halimifolia* were mixed with *P. australis*, south of the dead tree stump areas.

*Land Use and Population Density*

Land use in the surrounding area was residential. A boat landing was present east of the study area and houses on half-acre and quarter-acre plots bordered the wetland to the north and east. Many of the houses to the north possessed in-ground swimming pools.

*Tidal Characteristics*

Tidal Range

The mean tidal range (MHW–MLW) is 73 centimeters (2.4 feet) and the mean spring tidal range (MHHW-MLLW) is 82 centimeters (2.7 feet) (as measured at the Shinnecock Bay, Inside Outer Bar benchmark).

Tidal Inundation

Five stakes were used to measure tidal inundation (S1-S5) on October 26, 2004, one day before the monthly new moon. Retrieval and reading occurred on October 27, 2004. S1 was placed in the upper marsh on the edge of a salt panne that was surrounded by *S. patens* and *P. australis* growth. During flood tide this area received 30 centimeters of water. Stake S2, placed amidst *S. patens* growth and approximately 15 meters north of a cross ditch, revealed the upper middle marsh received 24 centimeters of water. Stake S3 was placed in the center of the middle marsh, near a pool. This area received 50 centimeters of water. Stake S4 was placed in the lower portion of the middle marsh, approximately 1.5 meters east of D2, among *P. australis* growth. This area of the marsh received 17 centimeters of water. Stake S5 was also placed in the lower portion of the middle marsh, among *S. patens* growth, approximately 7.5 meters east of stake S4. Tidal inundation in this area was 26 centimeters. The highest readings were obtained at stake S1 and stake S3 because they were taken in areas that contain water at low tide. These areas should therefore contain a greater amount of water at high tide than areas that were dry during low tide. The readings were similar for stake S2 and S5, indicating that the middle marsh received roughly the same amount of inundation. Despite being placed only 7.5 meters apart, the readings for stakes S4 and S5 differed by more than 8 centimeters. The area near stake S4 received less water than the area near stake S5. Growth of *P. australis* along ditch D2 was noted to be 15-20 cm higher than the ditch. Ditch maintenance may have increased elevation and facilitated *Phragmites australis* growth along this ditch. The difference in the vegetation present at stake S4 (*P. australis*) versus stake S5 (*S. patens*) correlates with lower tidal inundation in the area near stake S4.

Table 5-31. Pine Neck Tidal Inundation

| Stake | Marsh Placement | Tidal Inundation (centimeters) |
|---|---|---|
| S1 | Upper | 30 |
| S2 | Middle-upper portion | 24 |
| S3 | Middle | 50 |
| S4 | Middle-lower portion | 17 |
| S5 | Middle-lower portion | 26 |

*Stormwater*

No stormwater discharge pipes were observed at Pine Neck.

*Water Quality*

Temperature was similar (around 12.5 ºC) within and among the three ditches (D1, D2 and D3) studied. The highest reading among ditch samples was recorded at station D2B, in the middle marsh, where water temperature was generally lower than the temperature of the upper marsh. Salinity decreased toward the upper marsh, with the highest reading at station D2B. Ditch water depth increased toward the upper marsh along ditches D1 and D3, with depth being greater in ditch D1 versus ditch D3. This difference could be the result of ditch D1 being wider than ditch D3 and a partial blockage present at sample D3 B.

Temperature and salinity readings taken at each of the salt pannes (P1-P3), with the exception of the temperature reading from station P1, were greater than the temperature and salinity readings associated with ditches D1-D3. This trend typifies salt pannes. Trends in dissolved oxygen could not be analyzed due to instrument malfunction in the field (Table 5-32).

Table 5-32. Pine Neck Water Quality Measurements and Station Water Depth

| **Station** | **Station Location Characteristic** | **Temperature (ºC)** | **Salinity (ppt.)** | **Water Depth (cm)** |
|---|---|---|---|---|
| D1A | Middle-lower | 12.2 | 28.4 | 38 |
| D1B | Middle | 12.9 | 25.1 | 30 |
| D2C | Middle-lower | 12.1 | 28.7 | NR |
| D2B | Middle-lower | 15.3 | 29.7 | NR |
| D2A | Middle-upper | 12.5 | 28.5 | 25 |
| D3A | Middle-lower | 12.7 | 29.6 | 15 |
| D3B | Middle | 12.5 | 26.5 | 5 |
| P1 | Middle-upper | 12.6 | 27.9 | 15 |
| P2 | Upper marsh | 16.4 | 26.0 | NR |
| P3 | Upper marsh | 17.2 | 27.9 | 15 |

Note: NR indicates measurements that were "not recorded" for a specified sample
D = ditch P = panne
A, B, and C = samples taken along ditch

### *Ecology*

#### Tidal Vegetation

The vegetated wetland extended to the seaward edge of the study site, with no apparent sandy beach. Low marsh vegetation was primarily *S. alterniflora,* with *S. patens* and *P. australis* present along ditch edges. Middle marsh areas were covered with *Spartina patens* mixed with the short form of *S. alterniflora*. The area between ditches D2 and D3 was monospecific with the tall form of *S. alterniflora.* Large pockets of *S. alterniflora* were present in area between ditch D1 and D2. Upper marsh areas were dominated by *S. patens,* which surrounded the wetland. Macroalgae was present in the middle marsh near station D1B.

#### Phragmites

The common reed, *Phragmites australis*, bordered the entire wetland complex. This plant was present along ditch edges through out the study site; with growth heaviest along ditch D2 and the cross ditch joining ditches D2 and D3.

#### Upland Vegetation

Shrubs of *Iva frutescens* and *Baccharis halimifolia* were growing among *P. australis* along the eastern edge of the study area.

#### Wildlife

Fish were noted along D1 and D2. Shrimp and ribbed mussels were present in the low marsh at station D1A. It is also possible that animals such as muskrat travel utilize this marsh as runnels were observed in the middle marsh.

*Mosquito Habitat/History*

Ditching and Ditch Condition

Five northerly oriented ditches crossed the wetland along with one ditch oriented perpendicular to the others. Ditch water depth was greatest along ditch D1. Growth of *P. australis* along ditch D2 was noted to be 15-20 cm higher than the ditch. Ditch D3 had two occlusions due to *S. alterniflora* growth: the area near station D3B and the area toward the ditch mouth.

Pesticide Applications

Pine Neck has not been subjected to larvicide or adulticide applications. OMWM techniques have not been implemented at this site.

### 5.10.11 Stokes Poges

*Selection Criteria and Current Condition*

Stokes-Poges tidal marsh was selected as a PSA because it has vector control problems and is located in the middle of a residential area. It is a small, south shore fringing marsh with a healthy vegetation pattern despite tidal flow restriction. The installation of fish reservoirs and spurs might limit mosquito breeding, while minimizing the impact on vegetation. The wetland is included in the Town of Southampton's Area Management Plan for potential enhancement through wetland restoration and provisions of limited walking trails, a small-scale kayak launch, and an observation station.

*Location, Size, and Ownership*

The Stokes-Poges wetland is in Remsenburg in the Town of Southampton. Ownership is both private (1.2 hectares or 3.0 acres) and by the Town of Southampton (5.4 hectares or 13.3 acres). It is located south of Main Street, between Tuthill Lane and Halsey Road, and can be accessed via Bay View Road. The entire wetland measures approximately 6.6 hectares and the size of the area studied is approximately 180 x 1,320 meters.

*Topography and Waterbodies*

The Stokes-Poges wetland is situated within Hydrogeologic Zone VI, as delineated in the Long Island 208 Study. This south shore zone is a 'surface water impact area,' where groundwater discharges to Moriches Bay and the eastern portion of Great South Bay. Any contaminants present in the groundwater can have a major impact on surface waters in this area, as flushing rates in this part of the Bay are low.

Clumps of *Spartina patens* mixed with *Spartina alterniflora* (short form) covered the marsh. The ground between the clumps was muddy and wet. Numerous channels traversed the marsh, indicating animals, such as muskrat, regularly traveled through the marsh. The upland area was dry and consisted of *Phragmites australis* mixed with *Iva frutescens* and *Baccharis halimifolia*. Trees, such as Eastern Red Cedar (*Juniperus virginiana*), formed the terrestrial boundary of the marsh.

The wetland emptied into Moriches Bay, which opened to the ocean through Moriches Inlet. The northern portion of the wetland complex was narrow and contained the headwaters of a tidal creek. The creek spanned the entire length of the marsh and was approximately 0.2 meters long. The creek measured approximately three meters across in the southern portion and approximately 4.5 meters across in the northern portion, toward the headwaters. The straightness of its path suggested it has been channelized as part of the ditching process. The creek drained a series of small ponds south of South Country Road (Main Street). Various sized ponds were present throughout the wetland complex, three on the western edge, one on the eastern edge, and two in the center region. A pond that appeared on the 1956 USGS topographic map, in the southeastern portion of the wetland, has apparently dried up in the recent past, as vegetation appeared on the 2001 aerial photograph. Similarly, there was no evidence of another pond shown on the 1956 USGS map on the southern edge of the wetland. A series of salt pannes were present in the northern and southern portions of the study area.

### *Land Use and Population Density*

Land use within the area was large-lot residential. Many of the houses bordering the marsh to west appear to have in-ground swimming pools. The Town of Southampton has plans (South Shore Estuary Wetlands Restoration Study) to restore and enhance the wetland “using a combination of dredge spoil displacement and regrading and open marsh water management techniques.” The County estimated population density within 0.8 kilometers of the wetland to be 680 people.

### *Tidal Characteristics*

#### Tidal Range

The mean tidal range (MHW–MLW) was 15 centimeters (0.5 feet) and the mean spring tidal range (MHHW-MLLW) was 18 centimeters (0.6 feet) (as measured at Potunk Point, Moriches Bay).

#### Tidal Inundation

Five stakes were used to measure tidal inundation (S1-S5) on May 9, 2005 one day after the monthly full moon. Retrieval and reading occurred the following day. All the stakes were placed in the high marsh and on the eastern side of the marsh due to access limitations. Stakes S1, S2, and S5 were placed at the edge of the *Phragmites*. Stake S3 was placed inside the *Phragmites* and stake S4 inside a salt panne. All of the marsh is inundated at full moon high tide even as far upstream as the location of stake S5.

Table 5-33. Stokes Poges Tidal Inundation

| Stake | Marsh Placement | Tidal Inundation (centimeters) |
|---|---|---|
| S1 | High marsh | 20 |
| S2 | High marsh | 14 |
| S3 | High marsh | 14 |
| S4 | High marsh | 28 |
| S5 | High marsh | 19 |

### *Stormwater*

Several roadways end at the wetland complex and may therefore contribute to runoff. No stormwater discharge pipes were observed.

### *Water Quality*

Temperature was lowest toward the middle marsh and higher in the low marsh and upper marsh. The temperature in ditches D1 and D3 were higher than the temperature along ditch D4, while temperature along ditch D2, which was also the main creek, was constant. Salinity decreased slightly toward the upper marsh and was highest near the bay. The lowest reading (23.7 ppt.) was recorded at stations D3C and D4B. The saltier water of the creek indirectly influenced station D4A, which was located at the junction of ditch D4 and a cross ditch. Station D3C was located at a pond tributary, and likely had a lower salinity reading because it received freshwater input from the pond. The temperature and salinity measured in salt pannes P1 and P2 were similar to each other, with salinity being higher in panne P1. A direct connection between panne

P1 and the tidal creek may be the reason for the difference in salinity between the two salt pannes. Dissolved oxygen measurements could not be analyzed due to instrument malfunction in the field. Ditch water depth was greatest in the middle marsh, with readings being higher along ditch D2 and lower along ditch D1. Lower water depth along ditch D1 could be the result of this ditch not being directly connected to the creek or the bay (Table 5-34).

Table 5-34. Stokes-Poges and Station Water Depth and Water Quality Measurements

| Station | Station Location Characteristic | Water Depth (centimeters) | Temperature (°C) | Salinity (ppt.) |
|---|---|---|---|---|
| D1A | Low marsh | 45 | 10.6 | 30.5 |
| D1B | | 45 | 9.8 | 30.5 |
| D2A* | | 110 | 11.3 | 30.3 |
| D2B* | Middle marsh | 110 | 11.4 | 30.3 |
| D2C* | | 110 | 11.5 | 30.3 |
| D2D* | | 0.2 | 11.5 | 30.2 |
| D3A | | 60 | 10.8 | 30.4 |
| D3B | | 30 | 11.0 | 29.9 |
| D3C | Upper marsh | 20-25 | 12.0 | 23.7 |
| D4A | Middle marsh | 25 | 12.8 | 30.1 |
| D4B | Upper marsh | 25 | 12.2 | 23.7 |
| P1 | Middle marsh | 0.45 | 11.5 | 30.3 |
| P2 | | 25 | 12.3 | 29.7 |

Note: D = ditch P = panne
A, B, C, and D = samples taken along a ditch
* = samples taken along tidal creek

### *Ecology*

#### Tidal Vegetation

The low marsh was covered by the short form of *Spartina alterniflora* and the tall form of *S. alterniflora* along ditch edges. The short form of *S. alterniflora* became mixed with *S. patens* in the middle marsh, with *S. patens* becoming dominant toward the upper marsh. The common glasswort, *Salicornia europaea*, was present in the salt pannes.

#### Phragmites

The common reed (*Phragmites australis*) lined the entire perimeter of the site, clockwise, starting at the western edge, from Cutler Lane, north to Old Pond Road and continuing south to Bay View Road. Growth was heaviest along the eastern edge of the site and in the area which surrounded ditch D2, between Old Pond Road and Godfrey Lane.

Upland Vegetation

Shrubs of *I. frutescens* and *B. halimifolia* were mixed with *Phragmites australis* along the eastern and western borders of the study area. Bayberry (*Myrica pensylvanica*) was part of this mix on the western edge, near Cutler's Lane.

Wildlife

Large numbers of fish were observed along the northern portion of the tidal creek, with smaller numbers present in the salt pannes.

*Mosquito Habitat/History*

Ditching and Ditch Condition

The wetland has been grid ditched throughout the complex. Although the ditches do not always connect to the pannes, they do connect to all the ponds. The banks of the tidal creek were highly eroded, particularly in the central portion of the study area. Creek width was greatest toward the headwaters (approximately 3.3 meters). Ditch D3 traveled through several salt pannes. Mud (approximately 0.7 meters deep) lined all pannes and ditches, with the exception of the mouth of ditch D2. Samples taken at stations D2A and D2B revealed this area had a hard, sandy bottom. Water exiting the marsh at the mouth of the tidal creek has deposited a considerable amount of material into the bay. It is possible that this material eroded from the western shore of the marsh and was "pushed" out into the bay by ebb-tide flow from the creek. The difference in substrate type at the mouth of ditch D2 (hard and sandy) was likely the result of the fast flowing water noted in this area.

Pesticide Applications

The Stokes-Poges wetland has regularly received larvicide applications. OMWM techniques have not been implemented at this marsh.

### 5.10.12 West Gilgo Beach

*Selection Criteria and Current Condition*

The West Gilgo Beach salt marsh was chosen as a PSA because it is part of a barrier beach system located adjacent to a residential area. The marsh possesses a healthy vegetation pattern within the existing ditch system. These salt marshes are included in the New York Natural Heritage Program Reference Wetlands.

The ditch that runs the length of the marsh in an east/west direction limits the spread of *Phragmites australis*. The current ditch system effectively drains the marsh. At low tide, much of the ditch grid is dry or has stagnant water present. Numerous pannes are present throughout the marsh.

### *Location, Size, and Ownership*

The West Gilgo Beach salt marsh is located on Jones Island, a barrier island that separates the Atlantic Ocean from the Great South Bay. Over 120 hectares of "back barrier" marshes are located just west of Gilgo State Park. The marsh is owned by the New York State Department of Parks, Recreation, and Historical Preservation. The portion of the marsh studied is approximately 120 x 580 meters large.

### *Topography and Waterbodies*

Gilgo West is situated within Hydrogeologic Zone VII, as delineated in the Long Island 208 Study. This zone is defined as the south shore shallow flow system, in which the groundwater primarily moves laterally. Some upward flow may take place in this area as the groundwater discharges to surface water bodies.

A dredged channel, approximately 7.5 meters wide, separated the western from the eastern portion of the wetlands. An extension of this channel ran parallel to the barrier beach and provided boat access to the residents. A second channel, located on the western edge of the wetlands, provided additional boat access. Both channels connected to the 15 meters wide State Boating Channel that ran parallel to the beach and opened to the Bay. Because of the channels, most of the marsh edges were abrupt transitions to deeper water.

The channels effectively divided the West Gilgo Beach salt marshes into two segments. The western segment had short tidal creeks present at the northern edge, which ended in the low marsh. It also had numerous salt pannes, a fringe of *Phragmites australis* on the southern edge and little transition to marsh upland. The eastern segment had several lengthy tidal creeks extending into the middle marsh, patches of shrub upland, and a number of salt pannes.

### *Land Use and Population Density*

Land use within this area was primarily recreational, including boating, fishing, and swimming. A small residential community bordered the southern edge of the eastern segment.

### *Tidal Characteristics*

#### Tidal Range

The mean tidal range (MHW-MLW) was 30 centimeters (1.0 foot) and the mean spring tidal range (MHHW-MLLW) was 30 centimeters (1.2 feet) (as measured at the Bayshore benchmark).

#### Tidal Inundation

Five stakes measuring tidal inundation (stakes S1-S5) were placed in the marsh on October 8, 2004. Retrieval and reading occurred on October 9, 2004. Stake S1 was placed in the upper marsh, west of ditch D3, among *Spartina patens*. This area was covered by 29 cm of water during high tide. Stake S2 was fixed in the middle marsh, among *Iva frutescens*, west of ditch D3 and in line with stake S1. This area received 35 cm of water. Stake S3, also fixed in the middle marsh, was placed in the middle of a large salt panne, between ditches D2 and D3. This area was inundated with 42 cm of water during high tide. Stake S4 was placed in the lower portion of the middle marsh, in the middle of a salt panne that was at the start of a salt panne chain. The surrounding area received 59 cm of water. Stake S5 was placed in the low marsh, among *S. patens*. The area near this stake received 32 cm of water during flood tide. Tidal inundation appeared not to follow the typical trend of decreasing toward the upper marsh as readings were greatest in the middle marsh. This may have been due to numerous salt pannes being present in the middle marsh. The reading obtained in the low marsh (stake S5) may be similar to the reading obtained in the middle marsh (stake S2) because the areas were similar in elevation. This was supported by the existence of *S. patens* (Table 5-35).

Table 5-35. Gilgo West Tidal Inundation

| **Stake** | **Marsh Placement** | **Tidal Inundation (centimeters)** |
|---|---|---|
| S1 | Upper marsh | 29 |
| S2 | Middle marsh | 35 |
| S3 | Middle marsh | 42 |
| S4 | Middle marsh, toward low marsh | 59 |
| S5 | Low marsh | 32 |

### *Stormwater*

No stormwater discharge pipes were observed at the study site.

### *Water Quality*

Many ditches were dry at low tide (stations D2D and D2B east) and contained some *S. alterniflora*. Others contained stagnant water (stations D2B west and D2E), due to lack tidal exchange. Low elevation favored *Spartina alterniflora* growth in these ditches. Dry ditches contained less than one cm of water, while ditch areas with no water movement contained sizeable amounts of standing water. Temperature increased toward the upper marsh, while salinity varied with sample location. Low dissolved oxygen readings were consistent with the presence of stagnant water (Table 5-36).

Table 5-36. Gilgo West Water Quality Measurements and Ditch Water Description & Depth

| **Station** | **Station Location Characteristic** | **Water Depth (cm)** | **Temperature (ºC)** | **Salinity (ppt.)** | **Dissolved Oxygen (mg/L)** |
|---|---|---|---|---|---|
| D2A* | Low marsh | 17 | 19.2 | 27.5 | 10.0 |
| D2B west | Middle marsh, stagnant | 12 | 22.4 | 30.9 | 3.5 |
| D2B east | Middle marsh dry with *S. alterniflora* in ditch | <1 | NA | NA | NA |
| D2C | Upland area | NA | NA | NA | NA |
| D2D | Middle marsh, dry, with *S. alterniflora* in ditch | <1 | NA | NA | NA |
| D2E | Middle marsh, stagnant | 30 | 23.5 | 28.5 | 3.0 |
| D2F | Middle marsh | 5 | 23.7 | 33 | NR |

Note: NR-“not recorded” for a specified sample
NA-“not available” due to small amount of water present, or “not applicable”, if the sample location upland (2C).
D = ditch
A, B, C, D, E and F = samples taken along ditch
* = sample taken in tidal creek at mouth of ditch

### *Ecology*

#### Tidal Vegetation

Upper marsh vegetation was dominated by *Spartina patens*. A depression in the upper marsh contained Glasswort (*Salicornia europaea*), *Spartina alterniflora* and dead *S. patens*. *Spartina patens* became mixed with the short form of *S. alterniflora* toward the low marsh and covered the entire middle marsh area of the study site, with the exception of occasional pockets of *S. patens* and a horizontal strip of upland vegetation spanning the area between ditches D1-D4. The upland area supported spike grass (*Distichlis spicata*), sea myrtle (*Baccharis halmifolia*), marsh elder (*Iva frutescens*), bay berry (*Myrica pennsylvanica*), sea lavender (*Limonium nashii*) and poison ivy (*Toxicodenderon radicans*). The low marsh vegetation primarily consisted of *S. alterniflora*, with the short form present toward the middle marsh and the tall form present at the water’s edge. A moderately sized, oval-shaped area of *S. patens* was also present in the low marsh, near Stake S5 and north of the upland area. Common rock weed (*Fucus vesiculosis*) was present at the mouth of ditch D2, which bordered Great South Bay.

Phragmites

The southern edge of the study site was lined with *Phragmites australis* and was separated from the rest of the marsh by a trench approximately 2.4 to 3.0 meters wide. Some *P. australis* was present on the northern side of the trench and was present in areas covered by *S. patens*.

Upland Vegetation

*Phragmites australis* covered the northern edge of the study site that was separated from the rest of the marsh by a trench. A fringe of trees growing along Ocean Parkway flanked the *P. australis* border to the north, marking the terrestrial edge of the marsh.

Wildlife

Fiddler crabs (*Uca* spp.), mud snails (*Ilyanassa obsoleta.*), and ribbed mussels (*Geukensia demissa*) were present in the low marsh, at the mouth of ditch D2. A white crane was sighted wading in the low marsh. Large numbers of fish were noted in the middle marsh at station D2A and a small number of fish were noted in the salt panne near station D2E. Fish were notably absent from the areas near stations D2B (west) and 2E as water was stagnant in these areas.

*Mosquito Habitat/History*

Ditching and Ditch Condition

The West Gilgo Beach wetlands were regularly ditched every 60 meters (200 feet), in an approximately north-south orientation. Ditch water depth was highest at the mouth of D2 and decreased toward the upper marsh. Several areas adjacent to ditch D2 (stations 2B east and 2D) were essentially dry (less than 1.2 cm of water) due to *S. alterniflora* occlusions. The small amount of water that was present was stagnant. Bottom type varied from fine sand in the low marsh to mud in the middle marsh.

Pesticide Applications

West Gilgo beach marshes have regularly received larvicide applications. Adulticides have been applied near the small residential area adjacent to the marsh. OMWM techniques have been implemented in this area.

### 5.10.13 Gilgo Island

*Selection Criteria and Current Condition*

Gilgo Island was selected as a Primary Study Area because it is a medium-size, uninhabited, island exemplar.

*Location, Size and Ownership*

Gilgo Island is located in southwest Suffolk County in the western reaches of the Great South Bay. Gilgo Island is the largest of a series of islands that are positioned just north of Gilgo Beach, which is located on Jones Island, the barrier island west of Fire Island. Other islands near Gilgo Island are: Great Island, Elder Island, Wansers Island, Little Island, and Townsend Island.

Gilgo Island is approximately 110 hectares (273 acres). The island contains approximately 16 hectares (40 acres) of uplands and 94 hectares (233 acres) of marshland.

*Topography and Waterbodies*

Gilgo Island is located in Hydrogeological Zone VII as designated by the Long Island 208 Study. Hydrological Zone VII is an area likely to contribute water only to the shallow groundwater flow system and in general has horizontal flow.

Gilgo Island is dominated by low-marsh and high-marsh vegetation. It also includes significant upland areas. The low-marsh vegetation is predominantly tall and short-form *Spartina alterniflora*, with some *Salicornia* and *Limonium carolinianum*. High-marsh areas are dominated by *S. patens*, *Distichlis spicata*, *Iva frutescens*, *Phragmites australis*, and *Baccharis halimifolia*.

Gilgo Island is not tidally restricted. Two major tidal creeks run through the marsh, both heading west-east and entering the Great South Bay on the eastside of the island. The southernmost tidal creek begins as two tidal creeks that rejoin to create a larger tidal waterway.

Numerous ponds exist throughout Gilgo Island. Ponds observed in the study area range in size from 4 x 2 meters (13 x 6.5 feet), 3 centimeters (1 inch) deep to 45 x 15 meters (147 x 49 feet), 4 centimeters (1.5 inches) deep. One panne was observed, 8 x 2 meters (26 x 6.5 feet) in size, surrounded by dead *Salicornia.*

### *Land Use and Population Density*

Gilgo Island is an uninhabited island that is the property of Suffolk County. Several of the surrounding islands are designated State Tidal Wetlands and the undeveloped Gilgo State Park is located to the southeast of Gilgo Island. Two small barrier beach communities, Gilgo Beach and West Gilgo Beach, can be found south of Gilgo Island on Jones Island. Both of these communities have a mix of summer-only and year round residents.

The population of the Gilgo Island area is 330 within ½ mile radius and 389 within a two-mile radius.

### *Tidal Characteristics*

#### Tidal Range

The mean tidal range of Gilgo Island, based on the tidal information for nearby Gilgo Heading, is 34 centimeters (1.1 feet). The spring tidal range is 40 centimeters (1.3 feet) and the mean tide level is 15 centimeters (0.5 feet).

#### Tidal Inundation

In order to assess the amount of tidal inundation on the marsh surface, a tidal inundation study was completed during the lunar high tide in April 2005. Before the lunar high tide, stakes were placed in areas of standing water throughout the high marsh on April 8 and inundation measurements were collected later that day once the high tide had receded.

Stake S1 was placed in the high marsh amidst *Distichlis spicata.* This area received 9.5 centimeters of inundation. Stake S2 was also placed in high marsh among *Distichlis spicata* vegetation. This area received nine centimeters of inundation. Stake S3 was placed on the edge of a pond surrounded by *D. spicata* and *Spartina patens*. This area received eight centimeters of inundation. Stake S4 was placed in standing water adjacent to a ditch in *D. spicata* and *S. patens* vegetation. This area received 10.5 centimeters of inundation. Stake S5 was placed in standing water amidst *Salicornia.* This area received seven centimeters of inundation.

Skate S4 received the greatest amount of inundation. Ditch spurs located near this section allowed more inundation to reach this area. High marsh areas received approximately the same amount of inundation except for stake S5. Although stake S5 was placed in a low-lying area, ditch spurs from an adjacent ditch were directed away from this area.

Table 5-37. Gilgo Island Tidal Inundation

| Stake Number | Marsh Placement | Tidal Inundation (centimeters) |
|---|---|---|
| S1 | High marsh | 9.5 |
| S2 | High marsh | 9 |
| S3 | Edge of pond in high marsh | 7 |
| S4 | High marsh | 10.5 |
| S5 | High marsh | 7 |

### *Stormwater*

No stormwater discharge pipes were observed at Gilgo Island.

### *Water Quality*

Water quality measurements were collected from the head, mouth, and mid-point sections of the tidal creek and two selected ditches. Both ditches were analyzed at low tide. Temperature decreased slightly towards the mouth of both ditches and dissolved oxygen levels increased. Salinity remained constant across the marsh.

Table 5-38. Gilgo Island Water Quality Measurements and Ditch Water Depth

| Station | Sample Location Characteristics | Water Depth (centimeters) | Temp. (C) | Salinity (ppt.) | DO (mg/L) |
|---|---|---|---|---|---|
| TC-A | Intertidal marsh | >200 | 9.2 | 31.0 | 8.0 |
| TC-B | Intertidal marsh | - | 8.5 | 31.2 | 7.5 |
| TC-C | Intertidal marsh | 20 | 7.3 | 31.2 | 7.4 |
| D1A | Mouth of Ditch 1 | 42 | 8.4 | 31.3 | 7.4 |
| D1B | Mid section of Ditch 1 | 24 | 9.0 | 31.2 | 8.0 |
| D1C | Head of Ditch 1 | 3 | 10.9 | 30.3 | 2.1 |
| D2A | Mouth of Ditch 2 | 71 | 8.7 | 31.3 | 7.4 |
| D2B | Mid section of Ditch 2 | 45 | 8.5 | 31.3 | 6.7 |
| D2C | Head of Ditch 2 | 10 | 9.3 | 31.0 | 4.0 |

### *Ecology*

#### Tidal Vegetation

*Spartina alterniflora* is generally found in low-lying areas between ditches, and along the perimeter of the island. Most of the marsh is a mix of intertidal and high marsh vegetation, mainly *S. alterniflora, S. patens,* and *Distichlis spicata. Limonium carolinianum* is evident in low lying areas throughout the marsh. *Iva frutescens, Baccharis halimifolia, Phragmites australis* are common along sections of the outer border of the marsh.

Phragmites

*Phragmites* is found in few areas throughout Gilgo Island. *Phragmites* is located in sections of slightly higher elevation along the western and southern border of the marsh. *Phragmites* is noticeably absent from the interior of the marsh.

Wildlife

No fish were detected in the ditches or ponds. Sandpipers were observed utilizing a large pond (45 x 15 meters, 4 centimeters deep). Short-eared owls and a red fox were observed in high marsh areas.

*Mosquito Habitat/History*

Ditching and Ditch Condition

Parallel ditches cut through the majority of the marsh with numerous spurs. Gilgo Island is grid ditched and ditches are generally 61 meters (200 feet) apart. All ditches appear to have clear connections to the tidal creek.

Two ditches were analyzed at Gilgo Island (D1 and D2). Both ditches were open with clear connections to the tidal creek. Ditch D1 has a muddy substrate along the length of the ditch, while the substrate of ditch D2 was sandier.

Pesticide Applications

Gilgo Island is not aerially larvicided and no OMWM techniques have been implemented at this site. Adulticide is used to control mosquitoes near Gilgo Island.

### 5.10.14 West Watch Hill

*Selection Criteria and Current Condition*

West Watch Hill was chosen as a PSA because it is a barrier beach marsh and is directly adjacent to the hamlet of Davis Park and just west of the federally designated Wilderness Area.

*Location, Size and Ownership*

West Watch Hill is located within the Fire Island barrier island, due south of Patchogue, in the Town of Brookhaven. Great South Bay is located north of Fire Island and the Atlantic Ocean is south of the island.

West Watch Hill is approximately 9 hectares (23 acres) in size and is part of the Fire Island National Seashore. The Fire Island National Seashore contains the Otis G. Pike Wilderness Area, the only federally designated Wilderness Area in New York State. The Wilderness Area is approximately 500 hectares (1,300 acres) in size and stretches for nearly eight miles from Watch Hill to Smith Point County Park.

### *Topography and Waterbodies*

West Watch Hill is located in Hydrogeological Zone VI, as defined by the Long Island 208 Study. This area contains a thin freshwater lens groundwater regime, and does not lie in any of the major Long Island drainage basins.

The southern portion of West Watch Hill is dominated by dense stands of *Phragmites australis*. The center and northern portion of the marsh contains several ponds. However, this portion of the marsh is continually covered with approximately one foot of dark murky water, making it difficult to decipher the existence and boundaries of the ponds. No tidal creek exists at West Watch Hill.

### *Land Use and Population Density*

Watch Hill is a family beach destination, accessible by private boat, ferry (from Patchogue), or a short walk from Davis Park. It is one of the promoted locales within the Fire Island National Seashore and features a 200-slip marina, campsites, nature walks, public showers, and a lifeguarded beach. Slips accommodate boats up to 18 meters (60 feet) in length and the marina provides electric, water and a pump-out facility; it is open from May 15th through October 15th. The year-round population is only five within one-half mile of West Watch Hill and seven within two miles of the study area. Summer-time transient populations within the Seashore and resort populations in Davis Park will amount to several thousand.

### *Tidal Characteristics*

#### Tidal Range

West Watch Hill is significantly tidally restricted. Based on tidal information for nearby Point O' Woods, the mean tidal range for West Watch Hill is approximately 20 centimeters (0.7 feet). The spring tidal range is approximately 25 cm (0.8 feet) and mean tide is 10 cm (0.3 feet).

#### Tidal Inundation

In order to assess the amount of tidal inundation on the marsh surface in areas of high marsh, a tidal inundation study was completed during the lunar high tide in November 2004. Before the lunar high tide, stakes were placed in areas of standing water throughout the high marsh on November 25th and inundation measurements were collected on November 26th.

The inundation study revealed that West Watch Hill did not receive any inundation. A large berm on the north side of the marsh restricts tidal inundation from Great South Bay.

Table 5-39. West Watch Hill Tidal Inundation

| **Stake** | **Marsh Placement** | **Tidal Inundation (centimeters)** |
|---|---|---|
| S1 | Standing water in high marsh | 0 |
| S2 | High marsh, edge of Ditch 2 | 0 |
| S3 | Standing water in high marsh | 0 |
| S4 | Standing water in high marsh | 0 |
| S5 | Western perimeter | 0 |
| S6 | Standing water in high marsh | 0 |
| S7 | Standing water in high marsh | 0 |
| S8 | Mid-length Ditch 1 | 0 |
| S9 | Eastern perimeter | 0 |

#### *Stormwater*

No stormwater discharge pipes were observed at West Watch Hill.

#### *Water Quality*

West Watch Hill has very low salinities due to tidal restrictions and salt water entering the system only during larger storms and northerly winds. Water may also enter and leave the marsh system through groundwater.

Water quality measurements were collected from the head, mouth, and mid-point sections of two select ditches (D1 and D2). Water quality measurements were collected from the head, mouth, and the mid-point sections of ditches D1 and D2 during low tide.

Overall, temperature and salinity remained constant across the marsh. Dissolved oxygen decreased towards the mouths of both ditches.

Table 5-40. West Watch Hill Water Quality Data

| **Station** | **Sample Location Characteristics** | **Water Depth (centimeters)** | **Temp. (C)** | **Salinity (ppt.)** | **DO (mg/L)** |
|---|---|---|---|---|---|
| D1A | *Phragmites australis* | 70 | 10.6 | 0.6 | 0.96 |
| D1B | *S. patens, P. purpurascens, Scirpus maritimus* | 33 | 9.7 | 1.0 | 0.28 |
| D1C | *S. patens, P. purpurascens, S. maritimus, P. australis* | 45 | 10.5 | 0.5 | 2.03 |
| D2A | *P. purpurascens, S. maritimus, S. americanus, S. alterniflora* | 76 | 11.3 | 1.2 | 0.89 |
| D2B | *P. purpurascens, D. spicata, S. alterniflora, S. maritimus, Lemna minor* | 70 | 10.8 | 1.1 | 1.09 |
| D2C | *Phragmites, S. patens, P. purpurascens, Baccharis halimifolia* | 77 | 10.7 | 1.1 | 1.25 |

Note: Samples collected on 11/2/04, during low tide
D = ditch

## *Ecology*

### Tidal Vegetation

Small amounts of *Spartina alterniflora* is mixed in with high marsh vegetation throughout the areas of the marsh not dominated by *Phragmites australis*. *Pluchea purpurascens* (saltmarsh fleabane), *Scripus maritimus* (saltmarsh bulrush), and *Scirpus pungens* (common three-square) are the dominant vegetation in the high marsh. Other vegetation occurring throughout the high marsh includes *Spartina patens*, *Distichlis spicata* and *Baccharis halimifolia*.

### Phragmites

A large dense stand of *Phragmites australis* exists along the east, south and west perimeter of the marsh. A thin stand of *P. australis* dominates the berm along the northern boundary. The terminuses of all of the ditches running north to south become occluded with *P. australis*. Ferns are also present with the *P. australis* in the southern portion of the marsh.

### Wildlife

No fish were observed in the ditches, ponds, or areas of standing water throughout the marsh. Deer tracks were evident throughout the stands of *P. australis*.

*Mosquito Habitat/History*

Ditching and Ditch Condition

West Watch Hill has been subject to grid ditching that has not been maintained since the 1960s. The ditches are spaced approximately 60 meters (200 feet) apart. Due to the policies of the Fire Island National Seashore, there is very little active mosquito management in the marsh.

Two ditches (D1 and D2) were analyzed for general ditch characterization. Due to the significant amount of dark water across the marsh surface, it was difficult to characterize and measure the ditches. Both ditches were open but had no clear connections to the bay. Ditch D1 is occluded with *P. australis* near its mouth and with debris and wrack along its length. It eventually terminates in a large pond. Large amounts of duckweed (*Lemna minor*) were noted in the mid-section of ditch D2. The substrate of both ditches varied. Ditch D1 has a more muddy/peat substrate, while the substrate of ditch D2 is sandier.

Pesticide Applications

West Watch Hill does not receive aerial larvicide applications; however, adulticide has been applied in the vicinity at Davis Park. No OMWM techniques have been implemented at West Watch Hill.

The National Park Service has its own mosquito control plan that is available at on its website.

### 5.10.15 Hubbard Creek

*Selection Criteria and Current Condition*

The Hubbard Creek wetland was chosen as a PSA because it is relatively undisturbed, has experienced limited ditching, and is surrounded on most sides by a substantial forested area. The large buffer and sparsely populated surroundings contribute to minimal mosquito problems in this area. These salt marshes are included in the New York Natural Heritage Program Reference Wetlands.

Tidal inundation measurements indicate that upper marsh areas receive little or no tidal flow. The ditches present in this marsh are partially or totally occluded with plant growth.

*Location, Size, and Ownership*

The 102-hectare Hubbard Creek marsh is owned by Suffolk County. It is part of the Hubbard County Park, in Flanders, in the Town of Southampton. It is located north of Riverhead-

Hampton Bays Road and Red Creek Road and can be accessed via Upper Red Creek Road. Approximately 9.6 hectares (or 10 percent of the area) east of the creek mouth were studied. The study area is roughly bell-shaped and is widest at the low marsh (approximately 60 meters in width) and narrows toward the upper marsh (approximately 25 meters in width).

#### *Topography and Waterbodies*

##### Entire Area

The Hubbard Creek marsh is situated within Hydrogeologic Zone IV, as delineated in the Long Island 208 Study. This portion of the zone is a shallow flow system that discharges to streams and the marine waters of the Peconic Bay.

According to MacDonald and Edinger (2000), pannes cover approximately 6.5 hectares and those at the landward marsh margin contain up to 11 species of vascular plants. The Hubbard Creek wetland drains several smaller ponds inside Hubbard County Park and a series of ponds in the adjacent Sears-Bellows Pond County Park. Penny Pond is located in the eastern portion of the park, below Lower Red Creek Road. Hubbard Creek discharges at Cow Yard Beach, in Flanders Bay, which is in the western portion of Peconic Bay.

##### Study Area

Muddy, uneven ground in the low marsh became dry and firm in the middle marsh. In the upper marsh, the ground was sometimes muddy and uneven, with vegetation present in clumps. Numerous pannes of *Distichlis spicata* and the common glasswort, *Salicornia europaea*, were common throughout the middle marsh. Two separate areas of upland vegetation, which included stands of dead cedar trees, were present in the middle marsh.

A creek tributary, flowing through the study area, was widest in the low marsh and gradually narrowed toward the upland. An oval shaped pool (approximately six meters in diameter) was present in the low marsh, east of the widest part of the tributary.

#### *Land Use and Population Density*

The population density with in 0.8 kilometers of the Hubbard Creek marsh has been estimated by the County to be 1,100 people.

### *Tidal Characteristics*

#### Tidal Range

The mean tidal range (MHW–MLW) was 80 centimeters (2.8 feet) and the mean spring tidal range (MHHW-MLLW) was 100 centimeters (3.3 feet) (as measured at the Jamesport benchmark).

#### Tidal Inundation

Five stakes to measure tidal inundation (stakes S1-S5) were placed in the marsh on November 9, 2004, within several days of the monthly full moon. Stake retrieval and reading was completed on November 10, 2004. Tidal inundation data is found in Table 5-41. Stakes S3 and S5 are listed as receiving a *maximum* of two centimeters of water because the stakes had moved two centimeters out of the ground. Consequently, the distance between the portion of the stake in the soil and the treated portion of the stake was two centimeters. It was not possible, therefore, to determine whether inundation had occurred, though it would have been a maximum of two centimeters if it had occurred.

Stake S1 was placed in the upper marsh, amidst *Distichlis spicata*, 9.1 meters from cross ditch Da, near the terrestrial edge. It received two centimeters of water. The area near stake S1 likely received water from cross ditch Da, which is fed by the creek tributary.

Stake S2 was placed near the junction of ditches D2 and Db, near the middle marsh. This area received no measurable inundation during flood tide. The area near stake S2 may not have received a measurable amount of water due to its elevation.

Stake S3 was placed in the middle marsh, east of a stand of upland vegetation. The presence of upland vegetation near stake S3 suggests that this area probably received little, if any, tidal inundation.

Stake S4, placed on the edge of a stand of *Phragmites australis* in the low marsh received two centimeters of water. Stake S5 was placed immediately adjacent to an area of *Spartina patens*, *Scirpus pungens* (three-square sedge), and *Panicum virgatum* (switch grass). The presence of *P. australis* near stake S5 suggests that the area probably received little, if any, tidal inundation. This is confirmed by the presence of *Scirpus pungens*, a freshwater plant with low tolerance for saltwater. The source of freshwater is likely groundwater seepage.

Table 5-41. Hubbard Creek Tidal Inundation

| Stake | Marsh Placement | Tidal Inundation (centimeters) |
|---|---|---|
| S1 | Upper, near terrestrial border | 2 |
| S2 | Upper, near middle marsh | 0 |
| S3 | Middle | 2 |
| S4 | Low, near middle marsh | 2 |
| S5 | Low, near low marsh | 2 |

### *Stormwater*

No stormwater discharge pipes were observed. A single, small roadway bordered the marsh. Stormwater from the roadway flows into the adjacent upland area and probably has minimal impact on the marsh.

### *Water Quality*

Water quality samples were taken at various stations along three ditches (ditches D1, D2 and D3) and one salt panne (panne P1) (Table 5-42). All water quality parameters in ditch D1 varied considerably. Lower temperature and higher salinity corresponded with greater ditch depth. Water quality variation in ditch D1 is explained by its direct connection to the bay. Water depth at stations D2A, D2B, and D3A was constant. This is probably because station D3A was taken at the junction of ditches D2 and D3, which is also the mouth of ditch D2. Temperature and salinity were similar along ditch D2, possible because of ditch occlusions that restricted water flow. Temperature and salinity varied along ditch D3 as well. Temperature was lowest and salinity was highest at the junction of ditch D3 and the creek tributary, likely the result of direct tidal influence from the bay.

The temperature and salinity at station P1 differed from other samples taken along the creek tributary (stations D1A, D1B, and D1C) and along ditch D2. These differences may be due to the proximity of station P1 to the bay. Trends in dissolved oxygen could not be analyzed due to instrument malfunction in the field.

Table 5-42. Hubbard Creek Water Quality Measurements and Ditch Water Depth

| **Station** | **Station Location Characteristic** | **Water Depth (centimeters)** | **Temperature (ºC)** | **Salinity (ppt.)** |
|---|---|---|---|---|
| D1A* | Low marsh | NR | 6.5 | 22.7 |
| D1B* | Middle marsh | 5-7 | 6.9 | 21.4 |
| D1C* | Middle marsh | 30 | 7.3 | 17.4 |
| D1D | Upper marsh | 61 | 6.5 | 22.7 |
| D2A | Middle marsh, across from D1B | 15 | 7.9 | 16.7 |
| D2B | Middle marsh, across from D1C | 15 | 8 | 16.6 |
| D3A | Low marsh, junction of D2 | 15 | 7.6 | 17.2 |
| D3B | Upper marsh | NR | 8.3 | 15.7 |
| P2 | Low marsh in panne | NR | 6.6 | 24.7 |

Note: NR-"not recorded" for a specified sample
D = ditch P = panne
A, B, C and D = samples taken along ditch
* = samples taken in tidal creek which was also part of ditch 1

### *Ecology*

#### Vegetation

*Distichlis spicata* dominated the upper and middle marsh, with the tall form of *S. alterniflora* present along ditch edges. Toward the low marsh, *D. spicata* blended into *S. patens*, and *S. patens* was mixed with the short form of *S. alterniflora*. Green sea lettuce (*Ulva* spp.) and rockweed (*Fucus* spp.) were present at the water's edge near station D1A.

According to MacDonald and Edinger (2000), four rare plant species were observed in the wetland in 1997 and 1998 (*Fimbristylis castanea*, marsh fimbry; *Tripsacum dactyloides*, northern gamma grass; *Salicornia bigelovii*, dwarf glasswort; and seaside plantain, *Plantago maritime*).

#### Phragmites

The common reed (*Phragmites australis*) was present in a lobe shaped pattern along the southern edge of the study area, encroaching upon areas dominated by *D. spicata.* A smaller stand of *P. australis* was also present in the low marsh, west of ditch D3.

#### Upland Vegetation

*Baccharis halimifolia* was present in the upper marsh, west of Eastern Red Cedar trees (*Juniperus virginiana*) and near stake S1. Shrubs of *Iva frutescens* were present near cross ditch Da. *Iva frutescens* was also mixed with *P. australis* between cross ditches Db and Dc. Two separate areas of upland vegetation (*B. halimifolia*, *I. frutescens*, and *J. virginiana*) were present in the middle marsh. A larger upland area (approximately 90 x 30 meters) was located south of the tributary, near cross ditch Dd, and a smaller upland area was located south of ditch D2. Many dead *J. virginiana* were among the vegetation present in these two upland areas. Switch grass (*Panicum virgatum*) mixed with three-square sedge (*Scirpus pungens*) occurred south of the smaller pocket of upland vegetation. *Scirpus pungens* was also found in the upper marsh, along with *D. spicata*, north of where the tributary ends. The terrestrial border was composed of red oak (*Quercus rubra*), white oak (*Q. alba*), white pine (*Pinus strobus*) and numerous *J. virginiana*.

Wildlife

Deer tracks were visible in the mud of the path along the marsh border and several live deer were sighted in the upper marsh and the terrestrial border. Ribbed mussels (*Geukensia demissa*) were only present at station D1A.

*Mosquito Habitat/History*

Ditching and Ditch Condition

Three main ditches, the creek tributary (D1), one parallel ditch (ditch D2), and one perpendicular ditch (ditch D3), along with four cross ditches (Da, Db, Dc, and Dd) were present. Ditch D2, along with cross ditches Da, Db, Dc, were partially to totally occluded with *D. spicata* and the tall form of *S. alterniflora*. These occlusions occurred along part of cross ditch Da at the junction of ditches D2 and Db, and along part of cross ditch Dc and between cross ditches Dc and Dd. A hard sandy bottom was common to all ditches, with the exception of cross ditch Da, which had a muddy bottom (approximately 30 cm. in depth). The different bottom types may be due to the lack of tidal flow beyond cross ditch Da. The area around station panne P1 was wet and muddy, with a distinct sulfur odor present.

Pesticide Applications

The Hubbard Creek wetland is a prior OMWM site. It has not received larvicide or adulticide applications.

### 5.10.16 Cedar Beach

*Selection Criteria and Current Condition*

Cedar Beach was selected as a PSA because mosquito breeding occurs in the section of the marsh north of Cedar Beach Road and because this marsh could be considered a good candidate for restoring tidal flow.

*Location, Size and Ownership*

Cedar Beach is located in the Town of Southold, at the southeast tip of Great Hog Neck. The marsh is bounded to the east and south by Little Peconic Bay (Hog Neck Bay) and to the west by Cedar Beach Creek. Cedar Beach Creek extends north of Cedar Beach Road to a small extension of the saltmarsh. This section measures approximately six hectares (15 acres) and was the focus of this study. This section of Cedar Beach is privately owned amongst seven individuals.

*Topography and Waterbodies*

The wetlands at Cedar Beach lie in Hydrogeologic Zone IV, as delineated in the Long Island 208 Study. Fresh groundwater on the North Fork of Long Island is contained within a series of hydraulically isolated lenses that decline in thickness eastward. These lenses are isolated from the rest of the Long Island fresh groundwater system and have no adjacent freshwater to provide recharge.

Cedar Beach Creek runs along the western boundary of the marsh and continues underneath Cedar Beach Road via a culvert pipe and empties into Hog Neck Bay.

Numerous pannes and ponds exist were observed throughout the marsh. Most of the ponds are surrounded by a series of pannes with clumps of vegetation throughout. Ponds range in size from 1 x 1 meters (3.2 x 3.2 feet), 8 centimeters (7 inches) deep to 10 x 20 meters (33 x 66 feet) 29 centimeters (11 inches) deep and are located in areas of low marsh, high marsh and *Phragmites*. Several of the ponds observed had a murky green or murky white coloration on the water surface. These ponds are located in areas of high marsh and *Phragmites*. The discoloration on the water surface may be the result of certain bacteria within the mud of the pond. These bacteria produce sulfur as a byproduct of photosynthesis, which creates a white-colored layer on the marsh surface.

### *Land Use and Population Density*

Cedar Beach is bounded by undeveloped woodland to the north, low-density residential development to the west (half acre to one acre lots) and higher density houses to the east (quarter acre and smaller lots). The population within one-mile of the marsh is 1,985, and 5,820 within two miles.

### *Tidal Characteristics*

#### Tidal Range

Cedar Beach is tidally restricted via the culvert pipe underneath Cedar Beach Road. Based on the tidal information for Southold, the mean tidal range for Cedar Beach is approximately 70 centimeters. The spring tidal range is approximately 80 centimeters and the mean tide is 40 centimeters.

#### Tidal Inundation

In order to assess the amount of tidal inundation on the marsh surface in areas of high marsh, a tidal inundation study was completed during the lunar high tide in November 2004. Before the lunar high tide, stakes were placed in areas of standing water throughout the high marsh on November 11th and inundation measurements were collected on November 12th during low tide.

Five stakes were placed throughout the marsh. Stake S1 was placed in a panne surrounded by mixed high marsh and low marsh vegetation. This area received 13 cm of water. Stake S2 was placed in a panne also surrounded by mixed vegetation. This panne received 13 cm of water. Stake S3 was placed in a pond in the high marsh at the terminus of a ditch. This pond received the highest amount of inundation with 26.5 cm of water. Stake S4 was placed in a pond surrounded by *Spartina patens* and *Phragmites australis*. A white film was noted on the water surface of this pond. This pond received 15 cm of water. Stake S5 was placed along the bank of the tidal creek near the culvert pipe amidst *Phragmites australis* and upland vegetation. This area received 5.5 cm of water.

With the exception of stake S3, the amount of inundation in the ponds and pannes were generally consistent throughout the marsh. The pond at stake S3 received the highest amount of inundation, possibly because it is located at the terminus of a ditch.

Table 5-43. Cedar Beach Tidal Inundation

| **Stake** | **Marsh Placement** | **Tidal Inundation (centimeters)** |
|---|---|---|
| S1 | Panne | 13 |
| S2 | Panne | 13 |
| S3 | Pond | 26.5 |
| S4 | Pond | 15 |
| S5 | Edge of Cedar Creek near outfall pipe | 5.5 |

*Stormwater*

No stormwater discharge pipes were observed at Cedar Beach.

*Water Quality*

Water quality measurements were collected from the head, mouth, and mid-point sections of the tidal creek and two selected ditches (ditches D1 and D2). Both ditches bisect the marsh laterally. Both ditches were analyzed at low tide.

Overall, parameters remained constant with ditch depth along ditches D1 and D2. Dissolved oxygen became higher towards the mouth of ditch D2 as the water depth decreased.

Table 5-44. Cedar Beach Water Quality Data and Ditch Water Depth

| **Station** | **Sample Location Characteristics** | **Water Depth (centimeters)** | **Temp. (C)** | **Salinity (ppt.)** | **DO (mg/L)** |
|---|---|---|---|---|---|
| TC-A | *Spartina alterniflora* | >100 | 12.8 | 28.5 | 8.7 |
| TC-B | *Phragmites australis* | >100 | 12.9 | 28.8 | 8.98 |
| TC-C | *Phragmites australis* | 11 | 13.3 | - | 6.51 |
| D1A | *Phragmites, S. patens, D. spicata* | 24 | 12.7 | 29.0 | 7.9 |
| D1B | *S. alterniflora* | 25 | 12.3 | 29.0 | 7.8 |
| D1C | *Phragmites, Baccharis halimifolia* | 50 | 12.3 | 28.8 | 8.1 |
| D2A | *S. alterniflora, Iva frutescens, S. patens, D. spicata* | 1 | 12.2 | 28.4 | 8.9 |
| D2B | *Spartina alterniflora, S. patens, D. spicata* | 8 | 12.3 | 28.5 | 7.1 |
| D2C | *Phragmites, B. halimifolia, S. patens, D. spicata* | 13 | 11.7 | 29.0 | 7.3 |

Note: Samples collected on 11/11/04; 2 hours before low tide
D = ditch TC = tidal creek

*Ecology*

The portion of the marsh north of Cedar Beach Road consists mainly of high-marsh/low-marsh mixed vegetation with a large perimeter border of *Phragmites australis*. Numerous ponds and pannes exist throughout the center portion of the marsh.

Tidal Vegetation

*Spartina alterniflora* is the dominant vegetation in small sections along a small number of ditches. The majority of the inner marsh consists of a mix of *S. alterniflora*, *S. patens,* and *Distichlis spicata*. High marsh areas are limited to small segregated sections abutting the inner *Phragmites* border. These high marsh areas are dominated by *D. spicata* and *S. patens*. *Iva frutescens* and *Baccharis halimifolia* are also found sparsely throughout the high marsh, existing mostly along the perimeter of the marsh or in elevated areas of the marsh.

Phragmites

A large dense border of *Phragmites australis* surrounds the mid section of the marsh. This thick border of *P. australis* accounts for approximately one-half of the vegetation at Cedar Beach.

Wildlife

Moderate amounts of fish were observed in the ditches and few were noted in ponds. No water fowl was noted utilizing the marsh during site visits.

*Mosquito Habitat/History*

Ditching and Ditch Condition

The marsh at Cedar Beach has been subject to grid ditching. Ditches are spaced approximately 60 meters (200 feet) apart and run perpendicular to Cedar Beach Creek.

Two ditches (ditches D1 and D2) were analyzed for general ditch characterization. Both ditches run from east to west in the center portion of the marsh. The ditches are open with clear connections to the tidal creek and have a peat substrate. A berm approximately one meter (three feet) in length, dominated by *Iva frutescens,* exists at the mid-section of ditch D1. No berms were present along ditch D2. Both ditches have one connection to another ditch.

Pesticide Applications

Cedar Beach is not subject to aerial larviciding or adulticide applications in upland areas. No OMWM techniques have been implemented at either marsh at Cedar Beach.

### 5.10.17 Long Beach Bay

*Selection Criteria and Current Condition*

The Long Beach Bay wetlands were chosen as a PSA because mosquito breeding continues to occur at unacceptable levels despite the fact that OMWM techniques have been implemented.

### *Location, Size, and Ownership*

Long Beach Bay is a 105 hectare wetland complex located in Orient, in the Town of Southold. A large portion of the complex is owned and managed by NYSDEC. O'Connor and Terry (1972) estimated that it represents 24 percent of the 435 hectares of tidal marsh in the Township. The study site is adjacent to an agricultural area that is situated east of King Street and west of Peters Neck Road. The size of the study area is approximately 670 x 130 meters.

### *Topography and Waterbodies*

The wetlands of Long Beach Bay lie in Hydrogeologic Zone IV, as delineated in the Long Island 208 Study. Fresh groundwater on the North Fork of Long Island is contained within a series of hydraulically isolated lenses that decline in thickness eastward. These lenses are isolated from the rest of the Long Island fresh groundwater system and have no adjacent freshwater to provide recharge. Groundwater in Zone IV discharges to streams and the marine waters of the Peconic Bay.

King Street and Peters Neck Road bordered the study area to the north and east. Upland vegetation was present at the northern corner of the site, bordering King Street and in the southeastern end of the site, near Peters Neck Road. Much of the northeastern portion of the marsh was wet, except for a dry region of *Spartina patens* toward the seaward edge of the study area. A berm, likely from grading, bordered the entire eastern edge of the study area. The berm separated the residential and agricultural land from the marsh and supported upland vegetation.

Long Beach Bay is a semi-enclosed body of water that opens to Orient Harbor through a narrow channel at Peters Neck Point. The bay is bounded to the south by Orient Beach State Park, which is a narrow barrier dune system. The western portion of the wetland complex, adjacent to Orient Harbor, is narrow (maximum of 150 meters wide), and is bordered by a six to nine meter wide sandy beach. The wetland ends at Peters Neck Point.

A tidal creek flowing in from Orient Bay crossed through the study area. It began at an oval-shaped pool (approximately six meters in diameter), near the adjacent home present on the agricultural land and emptied into the bay by the bridge extending off Peters Neck Road. Several creek tributaries branched off the main creek and drained three oblong shaped ponds at the berm/marsh interface. Much of the ground in the areas surrounding the creek and ponds was wet.

### *Land Use and Population Density*

One large residential lot and agricultural land were located east of the berm. Four homes were built on the upland area at the southern end of Peters Neck Road

### *Tidal Characteristics*

#### Tidal Range

The mean tidal range (MHW–MLW) was 76 centimeters (2.5 feet) and the mean spring tidal range (MHHW-MLLW) was 84 centimeters (2.8 feet) (as measured at the Shelter Island Sound, Orient Harbor benchmark).

#### Tidal Inundation

Four stakes to measure tidal inundation (stakes S1-S3) were placed in the marsh, on October 12, 2004, one day before the monthly full moon. Retrieval and reading occurred on October 13, 2004. Stakes S1 through S3 were placed in the northwestern end of the site. Stake S1 was placed in the upper marsh, near a salt panne that is located at the southern edge of an *Iva frutescens* peninsula. This area of the marsh received 11 centimeters of water. Stake S2 was placed, in the middle marsh (approximately 45 meters south of stake S1), at the southern edge of a stand of *I. frutescens* that was surrounded by *Spartina patens*. During the flood tide, this area received 20 centimeters of water. Stake S3 was fixed at the edge of the *S. patens* and *S. alterniflora* interface, in the middle marsh (approximately 22 meters from stake S2). Tidal inundation by stake S3 was 20 centimeters (Table 5-45). The similarity in readings for stake S2 and stake S3 may be due to proximity of the stakes to one another.

Table 5-45. Long Beach Bay Tidal Inundation

| Stake | Marsh Placement | Tidal Inundation (centimeters) |
|---|---|---|
| S1 | Upper | 10 |
| S2 | Middle | 20 |
| S3 | Low | 20 |

### *Stormwater*

No stormwater discharge pipes were observed.

### *Water Quality*

#### Ditches

Temperature and salinity in ditches D1 and D2 were slightly higher in the middle marsh and dissolved oxygen increased toward the berm. Ditch water depth increased toward the low marsh (stations D1A to D3A) (Table 5-46).

Table 5-46. Long Beach Bay Ditch Water Depth and Water Quality Measurements

| **Station** | **Sample Location Characteristic** | **Water Depth (centimeters)** | **Temperature (ºC)** | **Salinity (ppt.)** | **Dissolved Oxygen (mg/L)** |
|---|---|---|---|---|---|
| D1A | Low marsh seaward edge of site | NR | 14.3 | 26.7 | 9.7 |
| D1B | Middle marsh seaward edge of site | 5 | 14.5 | 27.1 | 9.7 |
| D1C | Middle marsh seaward edge of site | 10 | 14.1 | 26.4 | 9.3 |
| D2A | Middle marsh middle of site | 10 | 14.7 | 27.7 | 10.2 |
| D2B | Upper marsh middle of site | NR | 14 | 26.5 | 10.3 |
| D3A | Low marsh near berm | 15-25 | 14 | 26.4 | 7.4 |
| D3B | Upper marsh near berm | 30 | 14 | 26.5 | 10.3 |

Note: NR- measurements “not recorded” for a specified sample
D = ditch
A, B, and C = samples taken along a ditch

#### Tidal Creek

Overall, dissolved oxygen readings were similar throughout the tidal creek Temperature was highest, while salinity and dissolved oxygen were lowest at T2. Water depth in the creek was approximately four times greater toward the mouth of the creek (T2) than at the head of the creek (T4). Samples at T1 were taken directly in Long Beach Bay, where temperature was lower and salinity and dissolved oxygen was higher (Table 5-47).

Table 5-47. Long Beach Bay, Tidal Creek Water Quality Measurements

| **Station** | **Station Location Characteristic** | **Water Depth (centimeters)** | **Temperature (ºC)** | **Salinity (ppt.)** | **Dissolved Oxygen (mg/L)** |
|---|---|---|---|---|---|
| T1 | Bridge over creek | NR | 15.9 | 29.1 | 10.6 |
| T2 | Low marsh, southeastern corner | 22 | 22.86 | 16.2 | 10.2 |
| T3 | Middle marsh, bend in creek | 91.4 | 14.8 | 27.4 | 10.6 |
| T4 | Head of creek, middle marsh | 10.2 | NR | NR | 10.4 |

Note: NR = measurements not recorded
T = tributary

#### Ponds

Temperature and salinity were slightly higher, while dissolved oxygen was slightly lower, in the pond (P1) versus the main tidal creek. Temperature and salinity may have been higher in the pond because it was an isolated body of water that is only indirectly influenced by water from the bay (Table 5-48). Water quality measurements between ponds P1 and P2 could not be compared because the second pond completely drained during low tide.

Table 5-48. Pond Water Quality Measurements

| **Station** | **Station Location Characteristic** | **Water Depth (centimeters)** | **Temperature (°C)** | **Salinity (ppt.)** | **Dissolved Oxygen (mg/L)** |
|---|---|---|---|---|---|
| P1 | Upper marsh | 15-45 | 14.9 | 28.8 | 10.0 |
| P2 | Upper marsh | NA | NA | NA | NA |

Note: NA = "not available" due to the small amount of water present
P = pond

### *Ecology*

#### Tidal Vegetation

This study site was dominated by *Spartina patens* with pockets of *S. alterniflora* mixed in toward upland area #1. *Spartina alterniflora* was present in the low marsh and along the seaward edge of the site. Dead *S. alterniflora* was present near the head of the tidal creek, at station T2. Red and green macroalgae (*Enteromorpha* spp. and *Ulva* spp.) were present at pond P2.

#### Phragmites

The common reed (*Phragmites australis*) was present along the berm.

#### Upland Vegetation

Upland vegetation was present at in the northern corner of the site, bordering King Street and in the southeastern end of the site, near Peters Neck Road. *Baccharis halimifolia* and *Iva frutescens* were growing along the entire length of the berm. A strip of Japanese knotweed (*Polygonium cuspidatum*) was present south of the residential property.

#### Wildlife

A small number of fish were found in ditches D1 and D2, while ribbed mussels (*Geukensia demissa*) were present in ditch D3. A small number of fish and mud snails (*Ilyanassa obsoleta*) were found near station T4. Larger fish, mud snails (*I. obsoleta*) and a greater number of *G. demissa* were observed in the samples taken in the northeastern part of the marsh (near stations T2 and T3).

### *Mosquito Habitat/History*

#### Ditching and Ditch Condition

Partial to total occlusions were common in the three main ditches (D) in the northwestern portion of the study site, which emptied into the head of the tidal creek. Clumps of *S. alterniflora* were growing in the middle of ditch D2, while eroded bases of *S. alterniflora* plants, along with collapsed banks and fast flowing water were present at the mouth of ditch D3. Occlusions were absent from the areas sampled along the main tidal creek (stations T1-T4). Ditch D4, located just east of station T2, no longer functions because it was completely filled in with *S. alterniflora*. The largest pond (P2) (approximately 30 x 7 meters) located toward the middle of the study site, completely drained during low tide. A muddy area inhabited with mud snails and red and green macroalgae (*Enteromorpha* spp. and *Ulva* spp.) remained. The presence of these types of macroalgae indicates that eutrophication may have occurred in this area.

#### Pesticide Applications

This wetland is a prior OMWM site. It has received no larvicide or adulticide applications.

## 5.10.18 Pipes Cove

### *Selection Criteria and Current Condition*

Pipes Cove Creek was selected as a PSA because it is a large wetland system fringing the Peconic Bay with vector control problems.

### *Location, Size and Ownership*

Pipes Cove is located on the south side of the North Fork of Long Island in the eastern portion of the Town of Southold. The southern portion of the marsh, south of Route 25 was the focus of this study.

The marsh at Pipes Cove is approximately 13 hectares (32 acres) in size and is divided laterally by the Long Island Rail Road (LIRR) train tracks. This marsh is privately owned amongst five individuals.

### *Topography and Waterbodies*

The wetlands of Pipes Cove lie in Hydrogeologic Zone IV, as delineated in the Long Island 208 Study. Fresh groundwater on the North Fork of Long Island is contained within a series of hydraulically isolated lenses that decline in thickness eastward. These lenses are isolated from the rest of the Long Island fresh groundwater system and have no adjacent freshwater to provide recharge. Groundwater in Zone IV discharges to streams and the marine waters of the Peconic Bay.

Pipes Cove is predominantly high marsh vegetation, consisting of *Distichlis spicata*, Spartina patens, and with intertidal vegetation fringing the ditches and tidal creek.

Pipes Cove Creek runs along the west side of the marsh and terminates north of Route 25. One pond and one panne are present within the marsh. The pond measures approximately 2 x 1 meters (6.5 x 3 feet) in size and was 13 centimeters (5 inches) deep during low tide in November. No fish were observed in the pond.

*Land Use and Population Density*

Predominant land uses surrounding the marsh are light residential and commercial (one welding and supply company). The population within one-half mile of Pipes Cove is 602 and 4,870 within two miles.

*Tidal Characteristics*

Tidal Range

Pipes Cove Creek empties into the waters of Pipes Cove. The creek is tidally restricted by a small peninsula with an opening less than six meters (20 feet) wide. Based on tidal information for Southold, the mean tidal range for Pipes Cove is approximately 70 centimeters (2.3 feet). The spring tidal range is approximately 82 centimeters (2.7 feet) and the mean tide is 39 centimeters (1.3 feet).

Tidal Inundation

In order to assess the amount of tidal inundation on the marsh surface, a tidal inundation study was completed during the lunar high tide in November 2004. Before the lunar high tide, stakes were placed in areas of standing water throughout the high marsh on November 11th and inundation measurements were collected on November 12th.

Stake S1 was placed in the high marsh in the western portion of the marsh. This area received 7 cm of water. Stake S2 was placed in a small dry panne. This panne received 34 cm of water. Stake S3 was placed in a small pond surrounded by high marsh vegetation. This pond received 39 cm of water. Stake S4 was placed amidst *D. spicata*. This area received 30.5 cm of water.

A greater amount of inundation was received in the eastern portion of the marsh, with the exception of the pond and panne, which may receive more inundation due to their low topography.

Table 5-49. Pipes Cove Tidal Inundation

| Stake | Marsh Placement | Tidal Inundation (centimeters) |
|---|---|---|
| S1 | High marsh | 7 |
| S2 | Panne | 34 |
| S3 | Pond | 39 |
| S4 | High marsh | 30.5 |

### *Stormwater*

No stormwater discharge pipes were observed at Pipes Cove.

### *Water Quality*

Water quality measurements were collected from the head, mouth, and mid-point sections of the tidal creek and two select ditches (D1 and D2) south of the LIRR tracks. Both ditches were analyzed during low tide.

Temperature and salinity remained constant throughout the marsh. Temperature and salinity were highest at the mid portion of ditches D1 and D2. Dissolved oxygen showed an increase towards the mouth of both ditches.

Table 5-50. Pipes Cove Water Quality Data and Ditch Water Depth

| Station | Sample Location Characteristics | Water Depth (centimeters) | Temp. (C) | Salinity (ppt.) | DO (mg/L) |
|---|---|---|---|---|---|
| TC-A | *S. alterniflora* | - | 12.7 | 27.1 | 9.95 |
| TC-B | *S. alterniflora* | - | 13.6 | 14.3 | 7.1 |
| TC-C | *Phragmites australis* | - | 12.3 | 3.8 | 6.7 |
| D1A | *S. alterniflora* | 9 | 13.0 | 21.0 | 7.5 |
| D1B | *S. alterniflora* | 26 | 14.1 | 26.1 | 3.7 |
| D1C | *S. alterniflora* | 3.5 | 12.9 | 22.2 | 1.3 |
| D2A | *S. alterniflora* | 15 | 13.8 | 18.6 | 7.0 |
| D2B | *S. alterniflora* | 4 | 14.0 | 22.9 | 6.9 |
| D2C | *S. alterniflora* | 7 | 13.3 | 21.8 | 6.6 |

Note: Samples were collected on 10/22/04, during low tide (12:20 p.m.)
D = ditch TC = tidal creek

### *Ecology*

#### Tidal Vegetation

Tall-form and short-form *S. alterniflora* are the dominant vegetation types along the ditches and lower portions of the tidal creek. Intertidal vegetation becomes sparse at the mouths of ditches and in some areas along sections the ditch edges.

A mix of *Distichlis spicata* and *S. patens* are the dominant vegetation in the high marsh. *Iva frutescens* appears in greater abundance along the edges of ditches north of the LIRR tracks.

#### Phragmites

*Phragmites* is very dense along the south side of Pipes Cove Creek and increases in vigor towards the head of the creek. *Phragmites* becomes mixed with *Iva frutescens* and *Baccharis halimifolia* in the northern border of the marsh.

#### Wildlife

Moderate numbers of mummichogs (*Fundulus heteroclitus*) and grass shrimp (*Palaemonetes pugio*) were observed in the ditches at Pipes Cove. Numerous fiddler crab (*Uca pugnax*) holes and ribbed mussels (*Geukensia demissa*) were noted in the areas of open mud along the banks of the tidal creek and exposed edges of ditches. Deer tracks and evidence of raccoons were also apparent throughout the marsh. An osprey nest exists south of the tidal creek on a small strip of marsh.

### *Mosquito Habitat/History*

#### Ditching and Ditch Condition

The marsh at Pipes Cove has been ditched. Ditches south of the LIRR tracks are widely spaced apart with few perpendicular ditches. The section of marsh north of the tracks has been grid ditched. Ditches in this section are spaced approximately 30 meters (100 feet) by 25 meters (80 feet) apart.

Two ditches (D1 and D2) were analyzed for general ditch characterization. The ditches are unplugged with clear connections to the tidal creek. Both ditches have a soft muddy substrate. The ditches widen at the mouth, almost doubling in width, creating open areas of mud with sparse vegetation.

#### Pesticide Applications

Aerial larvicide applications are performed throughout the marsh during the mosquito-breeding season. No OMWM techniques have been installed on this marsh.

### 5.10.19 Carlls River Corridor

*Selection Criteria and Current Condition*

The Carlls River corridor was chosen as a PSA because it is a fresh water wetland with a history of vector control; its location within suburbanized Babylon; and history of manipulation through channelization and damming means there is a potential for restoration activities.

As most of its watershed is suburbanized, stormwater exerts a major influence on the system. Stormwater flooding creates numerous temporary wet areas within the Carlls River corridor. Most of the area is criss-crossed by small pools and marshes, which may be connected to the river. Three large water bodies are important elements within the system.

*Location, Size, and Ownership*

The wetland corridor is approximately 5 kilometers in length and surrounds the banks of the Carlls River in Belmont Lake State Park. It is located in the Town of Babylon and is owned by New York State. The corridor is bordered to the north by August Road and to the south by Park Avenue. It is transected by Southern State Parkway, Sunrise Highway, and numerous dirt roads (accessible only to authorized vehicles).

*Waterbodies and Topography*

The Carlls River corridor lies in Hydrogeologic Zone VII, as delineated in the Long Island 208 Study. This zone is defined as the south shore shallow flow system, in which the groundwater primarily moves laterally. Upward flow also takes place in this area as the groundwater discharges to the surface water bodies of the corridor.

Belmont Lake, Carlls River, Southards Pond and three creeks are located within the wetland corridor. Belmont Lake is approximately 8 hectares (19 acres) in size and is located between August Road and Southern State Parkway. Carlls River begins in Belmont Lake and extends more than seven kilometers (25,000 feet) south, toward Great South Bay. Southards Pond is fed by two creeks, one draining Belmont Lake and one draining Elda Lake (located on the corridor's eastern branch), and drains via a third creek at its southern border. The pond is approximately 8 hectares (19 acres) in size.

An unnamed pond and a stormwater basin are also located within the wetland corridor. The pond is in the eastern branch of the corridor and is fed by the tributary connecting Elda Lake and

Southards Pond. The stormwater basin is associated with a housing development on Alicia Drive, which is located on the corridor's northeastern edge.

The northern portion of Belmont Lake State Park is a red maple-black gum swamp and mesic transition forest. The area surrounding Belmont Lake is primarily landscape cover with a riparian community present in a narrow band along the lake's north shore. Red maple-black gum swamp and mesic transition forest are present in the area between Southern State Parkway and Sunrise Highway, while red maple-black gum swamp, mesic transition forest, and upland forest are present south of Sunrise Highway to Park Avenue. These areas are typically moist, wet, and hummocky, with hollows or crypts common at the base of trees. Stagnant pools are present in areas along the dirt roads that traverse the park. Palustrine cultural areas are present along the shores of Belmont Lake, Southards Pond and portions of the southern end of Carlls River.

### *Land Use*

Heavily populated areas surround the wetlands, with the majority of the houses situated on lots smaller than a quarter acre. Two schools and a housing development are adjacent to the northeast portion of the corridor. The entire park is used for recreational pursuits year round, with boating, fishing, and swimming permitted in Belmont Lake and Southards Pond during the warmer months.

### *Stormwater*

It is likely that stormwater discharges directly into the system since most of the surrounding watershed areas are heavily urbanized. Stormwater flooding creates numerous stagnant pools along the unpaved roadways within Belmont Lake State Park. Stormwater pipes are present under the dirt road that runs parallel to Lafayette Road along the western edge of the park and in the stream channel that empties into the northwest corner of Southards Pond.

### *Ecology*

#### Freshwater Wetlands

The wetland communities include those that typically characterize riverine systems, including the coastal plain streams and ponds, red maple-black gum swamp, and several cultural palustrine environs (Edinger et al., 2002).

Coastal plain streams are typically slow moving, darkly stained, and support various species of submerged and floating aquatic vegetation.

Table 5-51 lists the plant species commonly found in coastal plain streams. Coastal plain ponds occur in kettle holes or depressions and support unique assemblages of plants due to the seasonal variation in water levels. These types of environments are considered to be regionally rare and support a large number of rare species (Edinger et al., 2002).

The types of trees listed in Table 5-52 typically surround coastal plain ponds. A dense understory of shrubs, such as sweet pepperbush (*Clethra alnifolia*) and winterberry (*Ilex verticillatum*), grow along the pond perimeter. Sedges, grasses, and flowering herbs are present in years of low water (USFWS, 1997). Species such as Walter's sedge (*Carex walteriana*), tall-beaked rush (*Rhynchospora macrostachya*), panic grasses (*Panicum* spp.), and bladderworts (*Utricularia purpurea*) are common. In contrast, floating leaved species such as waterweed (*Elodea* spp.), pondweed (*Potamogeton oakesianus*), white water lily (*Nymphaea odorata*), bayonet-rush (*Juncus militaris*), water milfoil (*Myriphyllum humile*), and naiad (*Najas flexilis*) dominate in years of highwater (Edinger et al., 2002). Table 5-53, Table 5-54, and Table 5-55 provide a listing of plant species commonly found in each zone.

### Inland Wetland Transitional Areas

Red maple-black gum swamp is present in the northern portion of Belmont Lake State Park, the area between Southern State Parkway and Sunrise Highway, and south of Sunrise Highway to Park Avenue (Edinger et al., 2002). This type of hardwood swamp derives its name from a red maple-black gum (*Acer rubrum, Nyssa sylvatica*), or black gum (*N. sylvatica*) dominated canopy. Drier areas of the swamp may be inhabited by stands of pitch pine (*Pinus rigida*).

A dense shrub layer is present and is characterized by numerous species such as: sweet pepperbush (*Clethra alnifolia*), high bush blueberry (*Vaccinium corymbosum*) and swamp azalea (*Rhododenderon viscosum*) (Edinger et al., 2002). Table 5-56 provides a list of species present in the shrub layer of a red maple-black gum swamp.

The herbaceous layer and groundcover consist of few species and may not be well developed. Cinnamon fern (*Osmunda cinnamomea*), netted chain fern (*Woodwardia areolata*), and skunk cabbage (*Symplocarpus foetidus*) comprise the herbaceous layer, while peat moss (*Sphagnum* spp.) covers the ground (Edinger et al., 2002). Table 5-57 provides a list of the herbaceous layer and ground cover species commonly found in a red maple-black gum swamp.

Beech-maple mesic transition forest is characterized by plant species adapted to living in a moderately moist habitat and are located between swamp and upland areas. Trees such as American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), American elm (*Ulmus americana*), and red oak (*Quercus rubra*) dominate the canopy. A sparse shrub layer commonly includes small trees and tall shrubs such as American hornbeam (*Carpinus caroliniana*) and witch hazel (*Hamamelis virginiana*), along with numerous tree seedlings and saplings. Groundcover plants include blue cohosh (*Caulophyllum thalictroides*) and jack-in-the-pulpit (*Arisaema triphyllum*). This habitat type is can be found in the northern portion of Belmont Lake State Park, the area between Southern State Parkway and Sunrise Highway, and south of Sunrise Highway to Park Avenue (Edinger et al., 2002). Species from each zone are listed in Table 5-58, Table 5-59, and Table 5-60.

Palustrine cultural areas are wetlands that have been created or modified by human activities to the extent that the composition of the present community markedly differs from the original community (Edinger et al., 2002). Examples of this type of subsystem can be found along the shores of Belmont Lake, Southards Pond, and along portions of the southern end of Carlls River.

#### Upland Vegetation

Upland forest vegetation is present in the area between Sunrise Highway and Park Avenue. These areas are dominated by white oak (*Quercus alba*), red oak (*Q. rubra*), sassafras (*Sassafras albidium*), red maple (*Acer rubrum*) and poison ivy (*Toxicodenderon radicans*).

#### Wildlife

Fish commonly found in the slow moving, darkly stained waters of coastal plain streams and ponds are listed in Table 5-61. The non-indigenous Asian clam (*Corbicula flumminea*) may also be present, as it has recently become established in coastal plain streams throughout New York State (Edinger et al., 2002).

Belmont Lake and Southards Pond support resident populations of warm water fishes, such as yellow perch (*Perca flavescens*) and large mouth bass (*Micropterus salmoides*). Trout are stocked into these waterbodies in the spring and fall. The shallow depth (approximately 3 meters) of these areas prevents sustainment of trout during summer months. Table 5-62 lists the species of fish present in Belmont Lake and Southards Pond.

Edinger et al. (2002) state "more data on characteristic fauna are needed," but similarities in plant species between red maple swamps and red maple-black gum swamps indicates that animal species that may inhabit red maple black gum swamps likely include wood ducks (*Aix sponsa*), beaver (*Castor canadensis*), and spotted salamanders (*Ambystoma maculatum*).

*Mosquito Information*

Habitat/Species

Mosquitoes are commonly found in wet depressions and among the root systems of the trees and grasses within the wetland corridor. Mosquitoes are also found in areas that contain large numbers of warm-blooded animals, such as farms and stables. The Belmont horse stable is located inside the Carlls River corridor.

In 2004, the County placed two gravid mosquito traps and three CDC light mosquito traps inside the park at the Belmont horse farm near Peconic Avenue and at a school located in the upper portion of the park's eastern branch. Mosquitoes carrying WNV were trapped near the Belmont horse stable, while mosquitoes carrying WNV and EEE were trapped near the horse stable by Peconic Avenue.

Table 5-51. Plant Species Associated with Coastal Plain Streams

| **Common Name** | **Scientific Name** |
|---|---|
| pondweeds | *Potamogeton pusillus* |
| | *P. ephihydrus* |
| naiads | *Najas flexilis* |
| | *N. guadalupensis* |
| waterweeds | *Elodea nuttallii* |
| | *E. canadensis* |
| | *E. densa* |
| stonewort | *Nitella* spp. |
| bladderwort | *Utricularia vulgaris* |
| duckweed | *Lemna minor* |
| tuckerman's quillwort | *Isoetes tuckermanii* |
| white water crowfoot | *Ranunculus trichophyllus* |
| watercress | *Nasturtium officinale* |

Table 5-52. Trees Associated with Coastal Plain Ponds

| **Common Name** | **Scientific Name** |
|---|---|
| White oak | *Quercus alba* |
| Red oak | *Quercus rubra* |
| Red maple | *Acer rubrum* |
| Eastern red cedar | *Juniperus virginiana* |
| Black cherry | *Rosaceae prunus* |

Table 5-53. Coastal Plain Pond Shrubs

| **Common Name** | **Scientific Name** |
|---|---|
| Leatherleaf | *Chamaedaphne calyculata* |
| Highbush blueberry | *Vaccinium corymbosium* |
| Sweet pepper bush | *Clethra alnifolia* |
| Male-berry | *Lyonia lingustrina* |
| Fetterbush | *Leucothoe racemosa* |
| Buttonbush | *Cephalanthus occidentalis* |
| Winterberry | *Ilex verticillatum* |

Table 5-54. Coastal Plain Pond Low Water Plants

| **Common Name** | **Scientific Name** |
|---|---|
| Pipewort | *Eriocaulon aquaticum* |
| Walter's sedge | *Carex walteriana* |
| Tall-beaked rush | *Rhynchospora macrostachya* |
| Panic grasses | *Panicum* spp. |
| Sundews | *Drosera* spp. |
| Canadian st. john's wort | *Hypericum canadense* |
| Gratiloa | *Gratioloa aurea* |
| Bladderworts | *Utricularia* spp. |
| Large yellow-eyed grass | *Xyris smalliana* |
| Purple loosestrife | *Lythrum salicaria* |

Table 5-55. Coastal Plain Pond High Water Plants

| **Common Name** | **Scientific Name** |
|---|---|
| Water shield | *Brasenia schreberi* |
| White water lily | *Nymphaea odorata* |
| Bayonet rush | *Juncus militaris* |
| Spikerush | *Eleocharis* spp. |
| Purple loosestrife | *Lythrum salicaria* |
| Purple bladderwort | *Utricularia purpurea* |
| Water milfoil | *Myriphyllum humile* |
| Naiad | *Najas flexilis* |
| Waterweed | *Elodea* spp. |
| Pond weed | *Potamogeton oakesianus* |
| Peat moss | *Sphagnum macrophyllum* |

Table 5-56. Red Maple-Black Gum Swamp Shrubs

| **Common Name** | **Scientific Name** |
|---|---|
| Inkberry | *Ilex glabra* |
| Highbush blueberry | *Vaccinium corymbosum* |
| Sweet pepperbush | *Clethra alnifolia* |
| Swamp azalea | *Rhododendron viscosum* |
| Fetterbush | *Leucothoe racemosa* |
| Dangleberry | *Gaylussacia frondosa* |
| Greenbrier | *Smilax glauca* |
| Virginia creeper | *Parthenocissus quinquefolia* |
| Poison ivy | *Toxicodenderon radicans* |

Table 5-57. Red Maple-Black Gum Swamp Herbaceous Layer and Ground Cover Plant Species

| **Common Name** | **Scientific Name** |
|---|---|
| Cinnamon Fern | *Osmunda cinnamomea* |
| Netted Chain Fern | *Woodwardia areolata* |
| Skunk Cabbage | *Symplocarpus foetidus* |
| Peat Moss | *Sphagnum* spp. |

Table 5-58. Beech-Maple Mesic Transition Forest Tree Species

| **Common Name** | **Scientific Name** |
|---|---|
| American beech | *Fagus grandifolia* |
| Tulip poplar | *Liriodenderon tulipfera* |
| Sweetgum | *Liquidambar styraciflua* |
| Pignut hickory | *Carya cordiformis Juglandacea* |
| American elm | *Ulmus americana* |
| White oak | *Quercus alba* |
| Red oak | *Q. rubra* |
| Eastern hop hornbeam | *Ostrya virginiana* |

Table 5-59. Beech-Maple Mesic Transition Forest Shrub Species

| **Common Name** | **Scientific Name** |
|---|---|
| American hornbeam | *Carpinus caroliniana* |
| Witch hazel | *Hamamelis virginiana* |
| Hobblebush | *Viburnum lantanoides* |
| Alternate leaved dogwood | *Cornus alterniflora* |
| Striped maple | *Acer pensylvanicum* |

Table 5-60. Beech-Maple Groundcover Species

| **Common Name** | **Scientific Name** |
|---|---|
| Blue cohosh | *Caulophyllum thalictroides* |
| Christmas fern | *Polystichum acrosticoides* |
| Jack-in-the-pulpit | *Arisaema triphyllum* |
| White baneberry | *Actaea pachypoda* |
| Bloodroot | *Sanguinaria canadensis* |
| False Solomon's seal | *Smilacina racemosa* |

Table 5-61. Coastal Plain Stream and Pond Fish Species

| **Common Name** | **Scientific Name** |
|---|---|
| American eel | *Anguilla rostrata* |
| Redfin pickerel | *Esox americanus* |
| Eastern banded killifish | *Fundulus diaphanus* |
| Pumpkinseed | *Lepomis gibbosus* |
| Banded sunfish | *Enneacanthus obesus* |
| Swamp darter | *Etheostoma fusiforma* |
| Largemouth bass | *Micropterus salmoides* |
| Chain pickerel | *Esox niger* |
| Brown bullhead | *Ictalurus nebulosus* |
| White perch | *Morone americana* |
| Black crappie | *Pomoxis nigromaculatus* |
| Yellow perch | *Perca flavescens* |
| Bluegill | *Lepomis macrochirus* |

Table 5-62. Fish Species Present in Belmont Lake and Southards Pond

| **Category** | **Common Name** | **Scientific Name** |
|---|---|---|
| Resident | Yellow perch | *Perca flavescens* |
| | Common carp | *Cyprinus nebulosus* |
| | Pumpkinseed | *Lepomis gibbosus* |
| | Brown bullhead | *Ictalurus nebulosus* |
| | Largemouth bass | *Micropterus salmoides* |
| | Bluegill | *Lepomis macrochirus* |
| Southards Pond only | Chain pickerel | *Esox niger* |
| Stocked | Brown trout | *Salmo trutta* |
| | Brook trout | *Salvelinus fontinalis* |
| | Rainbow trout | *Oncorhynchus mykiss* |

### 5.10.20 Manorville Red Maple Swamp

*Selection Criteria and Current Condition*

The Manorville Red Maple Swamp was chosen as a PSA because of its status as a unique and sensitive habitat and the presence of EEE. The area includes a regionally rare wetland community and is adjacent to two coastal plain ponds, which are also considered regionally rare wetland communities. The swamp contains rare species such as the tiger salamander (*Ambystoma tigrinum*), spotted turtle (*Clemmys guttata*), and Eastern hognose snake (*Heterodon platyrhinos*) (U.S. Fish and Wildlife Service, 1997). These swamps are included in the New York Natural Heritage Program Reference Wetlands.

*Location and Ownership*

The swamp is owned by Suffolk County. It is part of the Robert Cushman Peconic River County Park, which is located in the Town of Riverhead, south of the former Calverton Naval Weapons Industrial Reserve Plant. Swan Pond Road comprises the site's northern border, while River

Road and a dirt road bisect the site. The swamp wraps around the northeast corner of Swan Pond and covers the northern corridor between Swan Pond and an unnamed pond (west of Connecticut Avenue).

### *Topography and Waterbodies*

The Manorville swamp is located in the eastern portion of Hydrogeological Zone III. This zone is characterized by deep groundwater flow and Magothy recharge. Groundwater in this area is referred to as exceptionally high quality. The Manorville swamp also lies within the Central Suffolk SGPA. Manorville swamp groundwater generally discharges to the Peconic River as shallow flow.

Two coastal plain ponds lie in close proximity to the swamp, Swan Pond (approximately 24 hectares or 60 acres) and an unnamed pond (approximately 700 x 200 meters). These ponds are hydrologically connected by groundwater and by surface flow from the Peconic River (Edinger, 2002). The ponds occur in kettle holes or depressions in the Ronkonkoma moraine and support a unique assemblage of plants due to a seasonal variation in water levels (Edinger, 2002).

Red maple swamps commonly exist in poorly drained areas of inorganic soil. Numerous depressions and hummocks dominated by graminoid vegetation are typically present.

### *Land Use and Population Density*

The areas adjacent to the swamp are rural and undeveloped, with the exception of the Swan Pond Golf Club and the former Calverton NWIRP. Surrounding areas, such as Robert Cushman Peconic River County Park and the Peconic River, are used for outdoor recreation.

### *Stormwater*

No stormwater discharge pipes were observed. Stormwater sheet flow onto the swamp is expected from the Swan Pond Golf Club and the two roads that bisect the area.

### *Ecology*

#### Upland Vegetation

This type of swamp derives its name from a red maple (*Acer rubrum*) dominated canopy. Red maples may be co-dominant with several other hardwoods such as ashes (*Fraxinus excelsior*), elms (*Ulmus americana*), yellow birch (*Betula alleghaniensis*) and swamp white oak (*Quercus bicolor*). Bitternut hickory (*Carya cordiformis*), butternut (*Juglans cinerea*), black gum (*Nyssa* *sylvatica*), ironwood (*Carpinus carolinianus*) and white pine (*Pinus strobus*) trees are also present in smaller numbers. Table 5-63 provides a list of the tree species present in a typical red maple-hardwood swamp.

A dense shrub layer is present and is characterized by numerous species such as: spicebush (*Lindera benzion*), winterberry (*Ilex verticillata*), and high bush blueberry (*Vaccinium corymbosum*) (Edinger et al., 2002). Three other species are common to southeastern New York red maple hard wood swamps: black gum (*Nyssa sylvatica*), sweet pepperbush (*Clethra alniflora*), and swamp azalea (*Rhododendron viscosum*). Table 5-64 provides a list of the species typically present in the shrub layer of a red maple-hardwood swamp.

The herbaceous layer is primarily composed of ferns, such as the sensitive fern (*Onoclea sensibilis*) and cinnamon fern (*Osmunda cinnamomea*) and herbs, such as skunk cabbage (*Symplocarpus foetidus*) (Edinger et al., 2002). Table 5-65 provides a list of the herbaceous layer species commonly found in a red maple-hardwood swamp.

#### Wildlife

Red maple swamps support numerous wildlife species, such as wood duck (*Aix sponsa*), and obligate wetland breeders, such as spring peepers and the regionally rare tiger salamander (*Ambystoma tigrinum*) (USFWS, 1997). Table 5-66 lists the types of fauna occurring in red maple swamps.

### *Mosquito Information*

#### Habitat/Species

*Culiseta melanura* is commonly found in wet depressions and among the root systems of the trees and grasses of red maple swamps. This mosquito species has a flight range of up to five miles and primarily obtains blood meals from birds. It is a known vector of EEE and has tested positive for WNV.

#### Pesticide Applications

The last time the County applied adulticide to the area was 1994 and 1996 in response to the presence of EEE. A few “spot treatments” with Scourge were applied in 1996 and 1997 in response to complaints.

Table 5-63. Red Maple Hardwood Swamp Trees

| **Common Name** | **Scientific Name** |
|---|---|
| Red maple | *Acer rubrum* |
| Ashes | *Fraxinus pennsylvannica* |
| | *F. nigra* |
| | *F. americana* |
| Elms | *Ulmus americana* |
| | *U. rubra* |
| Yellow birch | *Betula alleghaniensis* |
| Swamp white oak | *Quercus bicolor* |
| Butternut | *Juglans cinerea* |
| Bitternut hickory | *Carya cordiformis* |
| Black gum | *Nyssa sylvatica* |
| Ironwood | *Carpinus carolinianus* |
| White pine | *Pinus strobus* |

Table 5-64. Red Maple Hardwood Swamp Shrubs

| **Common Name** | **Scientific Name** |
|---|---|
| Winterberry | *Ilex verticillata* |
| Spicebush | *Lindera benzoin* |
| Alders | *Alnus incana (sub species rugosa)* |
| | *A. serrulata* |
| Viburnums | *Viburnum recognitum* |
| | *V. cassinoides* |
| Highbush blueberry | *Vaccinium corymbosum* |
| Common elderberry | *Sambucus canadensis* |
| Shrubby dogwoods | *Cornus sericea* |
| Poison sumac | *Toxicodendron vernix* |
| Black ash | *Fraxinus nigra* |
| Black gum | *Nyssa sylvatica* |
| Sweet pepperbush | *Clethra alniflora* |
| Swamp azalea | *Rhododendron viscosum* |

Table 5-65. Red Maple-Hardwood Swamp Herbaceous Layer Species

| Plant Type | Common Name | Scientific Name |
|---|---|---|
| **Ferns** | Sensitive fern | *Onoclea sensibilis* |
| | Cinnamon fern | *Osmunda cinnamomea* |
| | Royal fern | *O. regalis* |
| | Marsh fern | *Thelypteris palustris* |
| | Crested wood fern | *Dryopteris critata* |
| | Spinulose wood fern | *D. carthusiana* |
| **Herbs** | Skunk cabbage | *Symplocarpus foetidus* |
| | White hellebore | *Veratum viride* |
| | Sedges | *Carex stricta* |
| | | *C. lacustris* |
| | | *C. intumescens* |
| | Jewelweed | *Impatiens capensis* |
| | False nettle | *Boehmeria cylindrica* |
| | Arrow arum | *Peltandra virginica* |
| | Tall meadow rue | *Thalictrum pubescens* |
| | Marsh marigold | *Caltha palustris* |

Table 5-66. Fauna Occurring in Red Maple Swamps

| Category | Common Name | Scientific Name |
|---|---|---|
| **Birds** | Wood duck | *Aix sponosa* |
| | American black duck | *Anas rubripes* |
| | Northern water thrush | *Seiurus noveboracensis* |
| **Mammals** | Beaver | *Castor canadensis* |
| | River otter | *Lutra canadensis* |
| | Mink | *Mustela vison* |
| | Muskrat | *Odatra zibethica* |
| **Amphibians** | Spring peeper | *Psuedacris c. crucifer* |
| | American toad | *Bufo americanis* |
| | Wood frog | *Rana sylvatica* |
| | Spotted salamander | *Ambystoma maculatum* |
| | Tiger salamander | *A. tigrinum* |
| | Common red-backed salamander | *Plethodon cinereus* |
| **Reptiles** | Eastern hognose snake | *Heterodon platyrhinos* |
| | Common garter snake | *Thamnophis sirtalis* |
| | Snapping turtle | *Chelydra serpentina* |

### 5.10.21 Mastic Freshwater Complex

*Selection Criteria and Current Condition*

The Mastic Freshwater Complex was selected as a PSA because it is a freshwater wetland site in a heavily populated area on Long Island's south shore. The area is also a Suffolk County vector control location and a risk assessment site.

#### 5.10.21.1 Location, Size and Ownership

The Mastic Freshwater Complex is located on the south shore of the Long Island in central Suffolk County. The study area is located between Pattersquash Creek to the west and Odell's

Creek/William Floyd Estate to the east. The Mastic Freshwater Complex is defined as the freshwater wetlands located within these boundaries. The Complex is broken into several smaller sections by a matrix of roads on the peninsula.

The Mastic Freshwater Complex is comprised of 30 hectares (75 acres) on privately owned residential lots. The William Floyd Estate, run by the National Park Service in Forge Point, is 248 hectares (613 acres) in size.

*Topography and Waterbodies*

The entire Mastic Beach peninsula is situated within the Hydrogeological Zone IV, as delineated in the Long Island 208 Study. This area is a portion of the south shore shallow flow system that discharges to Narrow Bay.

Groundwater plays a large role in the Mastic Freshwater Complex. Annual variations in the levels of the water table affect the moisture available to plants and animals in the area. Groundwater in this area primarily moves laterally toward the coastal waters, possible with some degree of upward flow as the groundwater discharges to the bay.

*Land Use and Population Density*

Most of the properties in the Mastic Freshwater Complex are residential development, although they sit within NYSDEC defined freshwater wetlands. This is mostly a result of housing development that occurred before the designation and regulation of freshwater wetlands in the state.

The majority of the homes in the area are single family built on lots of ranging from one-eight and one-half acre, and some larger. Several of the existing homes are "bungalows" that were previously designated for summertime use only but have been converted into year-round dwellings. The more recent residential developments are larger and more expansive. Population is 3,207 within one-half mile and 24,366 within two miles. The total population of Mastic Beach is 11,543.

*Tidal Characteristics*

Tidal Range

The Mastic Freshwater Complex is influenced by the tidal effects of the Great South Bay, Pattersquash Creek, and Odell's Creek. Tidal wetlands of the Mastic Freshwater Complex are connected by a series of culverts passing underneath the roadways that bisect the wetland habitats. Well-developed ditches connect the wetlands throughout the system. Some of the ditches were blocked either by manmade or natural obstructions.

Tidal variation in the Mastic Freshwater Complex is relatively small due to the degree that the system lies upstream from the salt marsh systems. Areas of fresh and brackish marsh have larger tidal ranges than the freshwater systems further inland.

The tidal variation in the nearby Great South Bay at Moriches inlet has a mean range of 2.9 feet, with a spring tide range of 3.5 feet, and a mean tide level of 1.5 feet.

### *Stormwater*

No stormwater discharge pipes were observed at Mastic Beach. Due to the low elevation along the south shore, stormwater sheet flow onto the southernmost portions of the Mastic Freshwater Complex is expected from Narrow Bay.

### *Ecology*

#### Upland Vegetation

Freshwater marshes occur in areas where the tide affects the flow of waters but where the average salinity is below 0.5 parts per thousand. Vegetation in these marshes is extremely diverse and consists predominantly of herbaceous species. Vegetation within the Mastic Freshwater Complex is characteristic of red maple – black gum swamps, freshwater tidal marshes, and shallow emergent freshwater marshes. There are large expanses of salt and brackish water marshes closer to the bays that influence the freshwater marshes in the area.

Red maple swamps are hardwood swamps that occur in poorly drained depressions, usually on inorganic soils. In any given stand, red maple is either the only canopy dominant, or it is co-dominant with one or more others including black ash, American elm, swamp white oak, butternut, and butternut hickory (Edinger et al., 2002). The shrub layer is usually well developed and may be quite dense. The herbaceous layer is often dominated by ferns. Plants species identified in the area and adjacent uplands are identified in Table 5-67.

Table 5-67. Vegetation Species Identified in the Mastic Freshwater Complex

| | | |
|---|---|---|
| Trees | Black cherry | *Prunis serotina* |
| | Black tupelo | *Nyssa sylvatica* |
| | Eastern red cedar | *Juniperous virginiana* |
| | Gray birch | *Betula populifolia* |
| | Pitch pine | *Pinus rigida* |
| | Red maple | *Acer rubrum* |
| | Swamp white oak | *Quercus bicolor* |
| | Weeping willow | *Salix babylonica* |
| Shrub layer | Common reed | *Phragmites australis* |
| | Greenbrier | *Smilax* spp. |
| | Groundsel bush | *Baccharis halimifolia* |
| | Highbush blueberry | *Vaccinium corymbosum* |
| | Honey suckle | *Lonicera spp.* |
| | Multiflora rose | *Rosa multiflora* |
| | Northern arrowood | *Virburnum recognitum* |
| | Northern bayberry | *Myrica pensylvanica* |
| | Poison ivy | *Rhus radicans* |
| | Shadbush | *Amelanchier arborea* |
| | Swamp azalea | *Rhododendron viscosum* |
| | Sweet pepperbush | *Clethra alnifolia* |
| | Three-square rush | *Scirpus americanus* |
| | Virginia creeper | *Parthenocissus quinquefolia* |
| | Winged sumac | *Rhus copallinum* |
| Herbaceous layer | Cinnamon fern | *Osmunda cinnamomea* |
| | Golden rod | *Solidago virgauria* |
| | Marsh fern | *Thelypteris palustris* |
| | Marsh mallow | *Athaea officinalis* |
| | Queen anne's lace | *Daucus carota* |
| | Royal fern | *Osmunda regalis* |
| | Skunk cabbage | *Symplocarpus foetidus* |
| | Swamp smartweed | *Polygonum coccineum* |

### Wildlife

Table-68 lists the types of fauna that are common to freshwater marshes.

### *Mosquito Habitat/History*

#### Ditching and Ditch Condition

Several of the salt and brackish marshes of the Mastic Freshwater Complex have been ditched and in places, these ditches extend into the tidal freshwater wetlands. Many of the freshwater wetlands are ditched and drain into the bays. There are a series of culverts that allow the ditches to flow naturally since the roadways bisect the freshwater wetlands. Some flow rates in the freshwater wetlands are considerably high.

Pesticide Applications

The Mastic Freshwater Complex has major vector control problems. Adulticides and larvicides are applied near the Mastic Freshwater Complex during the mosquito-breeding season.

Table 5-68. Fauna Common to Freshwater Marshes

| | | |
|---|---|---|
| Mammals | White-tailed Deer | *Odocoileus virginianus* |
| | Muskrat | *Ondatra zibethicus* |
| | Raccoon | *Procyon lotor* |
| Birds | Red-winged Black Bird | *Agelaius phoeniceus* |
| | American Coot | *Fulica americana* |
| | Canada Goose | *Branta canadensis* |
| | Belted Kingfisher | *Ceryle alcyon* |
| | Northern Harrier | *Circus cyaneus* |
| | American Black Duck | *Anas rubripes* |
| | Canvasback | *Aythya valisineria* |
| | Mallard | *Anas platyrhynchos* |
| | Great Egret | *Casmerodius albus* |
| | Snowy Egret | *Egretta thula* |
| | Black-crowned Night Heron | *Nycticorax nycticorax* |
| | Great Blue Heron | *Ardea herodias* |
| | Green Heron | *Butorides striatus* |
| | Osprey | *Pandion haliaetus* |
| | Tree Swallow | *Iridoprocne biocolor* |
| | Marsh Wren | *Cistothorus palustris* |
| | Common Yellowthroat | *Geothlypis trichas* |
| Reptiles | Eastern Mud Turtle | *Kinosternon subrubrum subrubrum* |
| | Snapping Turtle | *Chelydra serpentina* |
| | Spotted Turtle | *Clemmys guttata* |
| Amphibians | Eastern Ribbon Snake | *Thamnophis saurtius* |
| | Northern Water Snake | *Nerodia sipedon* |
| | Red-spotted Newt | *Notophthalmus viridescens viridescens* |
| | Spotted Salamander | *Ambystoma maculatum* |
| | Fowler's Toad | *Bufo woodhousei fowleri* |
| | Spring Peeper | *Hyla crucifer* |
| | Grey Treefrog | *Hyla versicolor* |
| | Wood Frog | *Rana sylvatica* |
| Insects | Black-winged Damselfly | *Calopteryx maculata* |
| | Green Darner | *Anas junius* |
| | Mosquito | *Culicidae* |
| | Spicebush Swallowtail | *Papilio Troilus* |

### 5.10.22 Wertheim National Wildlife Reserve

As part of the Long-Term Plan development process, the County received a permit to demonstrate progressive water management at WNWR. This OMWM approach stresses improvement in habitat for fish to consume mosquito larvae, creating a more diverse salt marsh that enhances wildlife and fish habitat values. This approach is an alternative to the maintenance of the grid ditch system established in the county in the 1900s and, where implemented elsewhere in the northeast US, has led to significant reductions in the acreage and instances of pesticide usage.

By restoring marsh hydrology and improving habitat for mosquito predators, such as fish, OMWM aims to reduce or eliminate chemical use to control mosquitoes while improving ecological conditions and increasing habitat diversity of the marsh. In particular, the project is intended to improve and restore the habitat of wetland-dependent birds and other Trust species, consistent with the goals and purposes of the National Wildlife Refuge system. The project is, thus, intended to combine mosquito control with wildlife habitat improvement and restoration.

The WNWR, located on the south shore of Long Island, is one of the last undeveloped estuary systems remaining on Long Island. Approximately half of the refuge consists of aquatic habitats including: marine waters with seagrass beds, intertidal salt marsh, high salt marsh, freshwater marsh, shrub swamp, and red maple swamp. The refuge's salt marshes, combined with the adjacent New York State-owned Fireplace Neck salt marsh, form the largest continuous salt marsh on Long Island.

The project site is comprised of 2,550 acres that is owned and managed by USFWS. The Carmans River, a state-designated Wild and Scenic River, meanders through the refuge and empties into the Great South Bay, at the southern end of WNWR. The project locations are along the east bank of the Carmans River, near its confluence with the bay. The project area has been grid-ditched, and is representative of salt marsh areas on which the county may choose to implement OMWM projects in the future, as the long-term plan is implemented.

It is likely that historic grid-ditching for mosquito control has substantially altered vegetation and habitat on Long Island marshes, although a lack of pre-ditching information makes it difficult to quantify the extent of those alterations. It is suspected that grid-ditching has reduced biodiversity and promoted monoculture vegetation, especially salt-meadow cordgrass (*Spartina patens*) and common reed (*Phragmites australis*). In addition, grid-ditching has not eliminated the need for larvicides, and occasionally adulticides, to effectively control mosquitoes. Better management of water on salt marshes could reduce or eliminate chemical usage for mosquito control. Ancillary benefits of improved water management would include a better functioning marsh, maintaining and enhancing biodiversity, improved fish and wildlife habitat, and a return to a more natural appearance by eliminating or reducing grid ditches.

A site design team consisting of representatives from USFWS, Ducks Unlimited, SCDHS, SCVC, Stony Brook University, Connecticut Department of Environmental Protection, and Cashin Associates produced a plan for the project. The team reviewed aerial photography, mosquito breeding site maps, topographic surveys with elevations, and salinity data to propose alterations for two areas, designated Area 1 and Area 2, at WNWR. The alterations to these marshes included the addition of tidal creeks, tidal channels, shallow spurs, sill channels and ponds. In addition, many of the old grid ditches were filled, and some mosquito-breeding depressions regraded using materials excavated during pond construction. These alterations were recommended based on existing hydrology, vegetation, habitat needs for fish and wildlife, existing mosquito breeding sites and anticipated new breeding sites that would develop once the marsh hydrology was restored.

Area 1 is approximately 39.5 acres and is characterized by widespread mosquito breeding and a high proportion of *Phragmites*. More natural water features, such as tidal creeks and ponds, were created to facilitate better movement of water and allow fish access to mosquito breeding sites. A perimeter channel was constructed along the *Spartina/Phragmites* interface on the eastern side to allow fish passage into mosquito breeding sites that are concentrated along the upland edge of the marsh. The channel is also intended to draw fresh water from this upland Phragmites area. The tidal channels provide habitat for estuarine fish and invertebrates that normally utilize natural tidal creeks. The ponds will be inhabited primarily by typical high marsh fauna, such as killifish, but will have exchange with the estuarine system via sill channels and/or through periodic flooding.

Eleven ponds were constructed in Area 1 with varying dimensions to attract certain bird species, such as black ducks, migratory water fowl, and shorebirds. Total acreage of the 11 ponds is approximately 1.48 acres. The ponds are shallow with a deeper sump approximately 2-3 feet in the middle, which allows fish to escape predators. The ponds have gradually sloping sides towards the edges allowing access for fish and birds, and supporting emergent vegetation. In addition, nine of the eleven grid ditches that are not needed for fish habitat were filled, using material from pond construction, and some mosquito-breeding depressions were eliminated by back-blading material from the ponds over these areas.

Area 2 consists of approximately 46.6 acres and is characterized by having less *Phragmites* than Area 1 and an increased abundance of low and high marsh vegetation. There are also fewer mosquito-breeding sites than in Area 1. Ten of the eleven ditches in this area were filled, essentially restoring vegetation lost due to pond construction. An existing perimeter channel on the east side of this area was extended. The plan proposed twelve ponds ranging in size to attract black ducks, migratory water fowl, and shorebirds. Total acreage of the twelve ponds is approximately 1.28 acres.

These salt marshes are included in the New York Natural Heritage Program Reference Wetlands.

## References for Section 5

Able, KW, DM Nemerson, R. Bush, and P. Light. 2001. Spatial variation in Delaware Bay (U.S.A.) marsh creek fish assemblages. *Estuaries* 24(3):441-452.

Able, KW, DM Nemerson, PR Light, and RO Bush. 2000. Initial response of fishes to marsh restoration at a former salt hay farm bordering Delaware Bay. pp. 749-773. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Acadmic Publishers, Boston, MA. 875 pp.

Adamowicz, SC, and CT Roman. 2005. New England salt marsh pools: a quantitative analysis of geomorphic and geographic features. *Wetlands* 25(2):279-288.

Adamowicz, SC, and CT Roman. 2002. *Initial Ecosystem Response of Salt Marshes to Ditch Plugging and Pool Creation: Experiments at Rachel Carson National Wildlife Refuge (Maine).* US Geological Survey, Narragansett, RI. 102 pp.

Alberts, JJ, Z. Filip, MT Price, DJ Williams, and MC Williams. 1988. Elemental composition, stable carbon isotope ratios and spectrophotometric properties of humic substances occurring in a salt marsh estuary. *Organic Geochemistry* 12(5):455-467.

Allen, JRL. 2000. Morphodynamics of Holocene salt marshes: a review sketch from the Atlantic and Southern North Sea coasts of Europe. *Quaternary Science Reviews* 19(12):1155-1231.

Allen, GM. 1939. *Bats.* Harvard University Press, Cambridge, MA.

Ambrecht, I., I. Perfecto, and J. Vandermeer. 2004. Enigmatic biodiversity correlations: antdiversity responds to diverse resources. *Science* 304:284-286.

Amsberry, L., MA Baker, PJ Ewanchuk, MD Bertness. 2000. Clonal integration and expansion of *Phragmites australis*. *Ecological Applications* 10:1110-1118.

Anonymous. 1991. *South Shore Mainland Marshes Focus Area Plan (Long Island), Atlantic Coast Joint Venture*. 21 pp. + appendix and table.

Austin, OL, Jr. 1983. The seaside sparrow assemblage: a review of its history and biology. pp. 13-18. In: Quay, TL, JB Funderbburg, Jr., DS Lee, EF Potter, and CS Robbins (eds.). *The Seaside Sparrow: Its Biology and Management*. Occasional Papers of the North Carolina Biological Survey, 1983-5. 174 pp.

Balmford, A., A. Bruner, P. Cooper, R. Costanza, S. Farbr, RE Green, M. Jenkins, P. Jeferiss, V. Jessamy, J. Madden, K. Munro, N. Myers, S. Naeem, J. Paavola, M. Rayment, S. Rosendo, J. Roughgarden, K. Trumper, and RK Turner. 2002. Economic reasons for conserving wild nature. *Science* 297:950-953.

Baltz DM, C. Rakocinski, and JW Fleeger. 1993. Microhabitat use by marsh-edge fishes in a Louisiana estuary. *Environmental Biology of Fishes* 36:109-126.

Barnegat Bay National Estuary Program. 2001. *The Barnegat Bay Estuary Program Characterization Report*. www.bbep.org/Char_Rpt/ch7/Chapter%207_text.htm

Bart, DJ, and JM Hartman. 2003. The role of large rhizome dispersal and low salinity windows in the establishment of common reed, *Phragmites australis*, in salt marshes: new links to human activities. *Estuaries* 26(2B):436-443.

Bart, DJ, and JM Hartman. 2002. Constraints on the establishment of *Phragmites australis* in a New Jersey salt marsh and possible links to human disturbance. *Wetlands* 22:201-213.

Bertness, MD. 1999. *The Ecology of Atlantic Shorelines*. Sindauer Associates, Inc., Sunderland, MA. 417 pp.

Bertness, MD, 1992. The ecology of a New England salt marsh. *American Scientist* 80:260-268.

Bertness, MD. 1991. Zonation of *Spartina patens* and *Spartina alterniflora* in a New England salt marsh. *Ecology* 72(1):138-148.

Bertness, MD, and AM Ellison. 1987. Determinants of pattern in a New England salt marsh plant community. *Ecological Monographs* 57(2):129-147.

Bertness, MD, PJ Ewanchuk, and BR Silliman. 2002. Anthropogenic modification of New England salt marsh landscapes. *Proceedings of the National Academy of Sciences* 99(3):1395-1398.

Bertness, MD, and GH Leonard. 1997. The role of positive interactions in communities: lessons from intertidal habitats. *Ecology* 78(7):1976-1989.

Bertness, MD, and SC Pennings. 2000. Spatial variation in process and pattern in salt marsh plant communities in eastern North America. pp. 39- 57. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Acadmic Publishers, Boston, MA. 875 pp.

Bertness, M, BR Silliman, and R. Jefferies. 2004. Salt marshes under siege. *American Scientist* 92:54-61.

Blum, JL. 1968. Salt marsh *Spartinas* and associated algae. *Ecological Monographs* 38(3):199-221.

Bodola, A. 1969. An evaluation of the effectiveness of natural pools, blind sumps and champagne pools in reducing mosquito production on a salt marsh. *Proceedings of the New Jersey Mosquito Extermination Association* 57:45-70.

Borrer, DJ, DM DeLong, and CA Triplehorn. 1981. *An Introduction to the Study of Insects*. CBS College Publishing, New York, NY.

Bourn, WS, and C. Cottam. 1950. *Some Biological Effects of Ditching Tide Water Marshes*. US Fish and Wildlife Research Report 19. 30 pp. + oversize figures.

Briggs, PT, and JS O'Connor. 1971. A comparison of shore-zone fishes from naturally-vegetated and sandfilled bottoms of Great South Bay. *New York Fish and Game Journal* 18:15-41.

Browne, S, S Crocoll, D Goetke, N Heaslip, T Kerpez, K Kogut, S Sanford, and D Spada. 1995. *New York State Department of Environmental Conservation Freshwater Wetlands Delineation Manual.* New York State Department of Environmental Conservation, Albany, NY. 44 pp.

Brush, T., RA Lent, T. Hruby, BA Harrington, RM Marshall, and WG Montgomery. 1986. Habitat use by salt marsh birds and response to open marsh water management. *Colonial Waterbirds* 9:189-195.

Buchsbaum, R. 2001. Coastal marsh management. Chapter 11. In: Kent, DM (ed.). *Applied Wetland Science and Technology*. CRC Press, Boca Raton, FL.

Buchsbaum, R., A. Cooper, and J. LeBlanc. 1998. Habitat issues faced by the Plum Island Sound estuary. pp. 148-158. In: Buchsbaum, R., T. Purinton, and B. Magnuson (eds.). *A Study of the Marine Resources of the Parker River-Plum Island Sound Estuary: An Update After 30 Years*. Massachusetts Office of Coastal Zone Management.

Burdick, DM, M. Dionne, RM Boumas, and FT Short. 1997. Ecological responses to tidal restorations of two northern New England salt marshes. *Wetlands Ecology and Management* 4(2):129-144.

Burger, J. 1991. Coastal landscapes, coastal colonies, and seabirds. *Reviews in Aquatic Sciences* 41(1):23-43.

Buxton, HT, and DA Smolensky. 1999. *Simulation of the Effects of Development of the Ground-water Flow System of Long Island, New York*. Water-Resources Investigations Report 98-4069, US Geological Survey, Coram, NY. 57 pp.

CA-CE. 2004. *Long Island Mosquitoes*. Suffolk County Vector Control and Wetlands Management Long-Term Plan and Environmental Impact Statement, Task 3 (Literature Search), Book 1. Suffolk County Department of Health Services, Yaphank, NY. www.suffolkmosquitocontrolplan.org. 58 pp. + appendix.

CPBJPPC. 1995. *Central Pine Barrens Comprehensive Land Use Plan*. Central Pine Barrens Joint Planning and Policy Commission, Great River, NY. 2 Vols.

Cademartori, EA. 2000. *An Assessment of Salt Marsh Changes in Southern Stony Brook Harbor: Implications for Future Management*. Masters Thesis, SUNY at Stony Brook. 121 pp.

Cai, WJ, ZHA Wang,. and YC Wang. 2003. The role of marsh-dominated heterotrophic continental margins in transport of CO2 between the atmosphere, the land-sea interface and the ocean. *Geophysical Research Letters* 30(16), pp. OCE 3-1.

Campbell, CAR. 1907. *Bats, Dollars and Mosquitoes*. 2002 reprint: University Press of the Pacific (through Ingram Book Group, La Vergne, TN). 360 pp.

Capotosto, P. 2000. Nott Island marsh restoration on the CT River. *Northeastern Mosquito Control Association*, December. p. 35.

Carter, V. 1996. Wetland hydrology, water quality, and associated functions. *National Water Summary on Wetland Resources*. US Geological Survey Water-Supply Paper 2425:35-48.

Carter, TC, MA Menzel, BR Chapman, and KV Miller. 2004. Partitioning of food resources by synoptic Eastern red (*Lasiurus borealis*), Seminole (*L. seminolus*) and evening (*Nycticeius humeralis*) bats. *American Midland Naturalist* 151:186-191.

Cashin Associates. 2006. *Salt Marsh Losses*. Suffolk County Vector Control and Wetlands Management Long-Term Plan and Environmental Impact Statement, Task 3 (Literature Search), Book 9, Part 4. Suffolk County Department of Health Services, Yaphank, NY. www.suffolkmosquitocontrolplan.org. 78 pp.

Cashin Associates. 2005a. *Salt Marsh Function and Value*. Suffolk County Vector Control and Wetlands Management Long-Term Plan and Environmental Impact Statement, Task 3 (Literature Search), Book 9, Part 2. Suffolk County Department of Health Services, Yaphank, NY. www.suffolkmosquitocontrolplan.org. 41 pp.

Cashin Associates. 2005b. *Human Health Risks Associated with Mosquito-borne Pathogens in Suffolk County, NY.* Suffolk County Vector Control and Wetlands Management Long-Term Plan and Environmental Impact Statement, Task 3 (Literature Search), Book 2 Part 2. Suffolk County Department of Health Services, Yaphank, NY. www.suffolkmosquitocontrolplan.org. 59 pp.

Cashin Associates. 2005c. *Nuisance versus Vector Control Decisions: Public Health Implications for Suffolk County.* Suffolk County Vector Control and Wetlands Management Long-Term Plan and Environmental Impact Statement, Task 4 (Current Operations). Suffolk County Department of Health Services, Yaphank, NY. www.suffolkmosquitocontrolplan.org. 20 pp. + appendices.

Cashin Associates. 2005d. *Eastern Equine Encephalitis and Salt Marsh Mosquitoes*. Suffolk County Vector Control and Wetlands Management Long-Term Plan and Environmental Impact Statement, Task 4 (Current Operations). Suffolk County Department of Health Services, Yaphank, NY. www.suffolkmosquitocontrolplan.org. 17 pp.

Cashin Associates. 2004a. *Natural and Managed Salt Marshes*. Suffolk County Vector Control and Wetlands Management Long-Term Plan and Environmental Impact Statement, Task 3 (Literature Search), Book 9, Part 3. Suffolk County Department of Health Services, Yaphank, NY. www.suffolkmosquitocontrolplan.org. 165 pp.

Cashin Associates. 2004b. *Salt Marsh Health*. Suffolk County Vector Control and Wetlands Management Long-Term Plan and Environmental Impact Statement, Task 3 (Literature Search), Book 9, Part 3. Suffolk County Department of Health Services, Yaphank, NY. www.suffolkmosquitocontrolplan.org. 41 pp.

Cashin Associates. 2004c. *Health and Environmental Assessment for the Peconic River*. Suffolk County Department of Health Services, Hauppauge, NY. 3 vols.

Cashin Associates. 2002. Carmans River Environmental Assessment, Suffolk County, New York. Suffolk County Department of Health Services, Hauppauge, NY. 2 vols.

Chambers, RM, TJ Mozdzer, and JC Ambrose. 1998. Effects of salinity and sulfide on the distribution of *Phragmites australis* and *Spartina alterniflora* in a tidal salt marsh. *Aquatic Botany* 62:161-169.

Chambers, RM, DT Osgood, DJ Bart, and F. Monalto. 2003. *Phragmites australis* invasion and expansion in tidal wetlands: interactions among salinity, sulfide, and hydrology. *Estuaries* 26(2B):398-406.

Chapman, VJ. 1974 *Salt Marshes and Salt Deserts of the World*. 2nd. Ed. Strauss & Cramer GMBH, Leutershausen, Germany. 392 pp. + 101 pp. added for 2nd. Ed.

Childers, DL, Day, JW, and H. McKellar. 2000. Twenty more years of marsh and estuarine flux studies: Revisiting Nixon (1980). In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Acadmic Publishers, Boston, MA. 875 pp.

Chowdhury, SH, and E. Rahman. 1984. Food preference and rate of feeding in some dragonfly larvae (Anisoptera: Odonata). *Annals of Entomology* 2(1):1-6.

Christie, GD. 1993. Marsh water management on Nantucket. *Northeastern Mosquito Control Association*, November.

Christie, GD. 1990. *Manual of Methods for Open Marsh Water Management in Rhode Island*. Rhode Island Pesticide Relief Advisory Board, North Kingstown, RI. 24 pp. + appendices.

Cicchetti, G., and RJ Diaz. 2000. Types of salt marsh edge and export of trophic energy from marshes to deeper habitats. pp. 515-541. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Acadmic Publishers, Boston, MA. 875 pp.

Clarke, JA, BA Harrington, T. Hruby, and FE Wasserman. 1984. The effect of ditching for mosquito control on salt marsh use by birds in Rowley, Massachusetts. *Journal of Field Ornithology* 55(2):160-180.

Collins, JN, LM Collins, LB Leopold, and VH Resh. 1986. The influence of mosquito control ditches on the geomorphology of tidal marshes in the San Francisco Bay area: the evolution of salt marsh mosquito habitats. *Proceedings of the California Mosquito and Vector Control Association* 54:91-95.

Corrigan, R. 1997. Do bats control mosquitoes? *Pest Control Technology Magazine*. September.

Costanza, R. 2003. Social goals and the valuation of natural capital. *Environmental Monitoring and Assessment* 86(1-2):19-28.

Costanza, R. 2000. Social goals and the valuation of ecosystem services. *Ecosystems*, 3(1):4-10.

Cowan, DP, T., Hruby, LS Litwin, and RA Lent. 1986. *Open Marsh Management on Great South Bay, Islip, New York: Baseline Study: 1984-1985*. Cornell University Laboratory of Ornithology, Islip, New York. 101 pp.

Cowardin, LM, V Carter, FC Golet, and ET LaRoe. 1979. *Classification of Wetlands and Deepwater Habitats of the United States.* US Fish and Wildlife Service, FWS/OBJ-79/31. Washington, DC. 103 pp.

Craig, JK, and LB Crowder. 2000. Factors influencing habitat selection in fishes with a review of marsh ecosystems. pp. 241- 266. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Acadmic Publishers, Boston, MA. 875 pp.

Crooks, S., and RK Turner. 1999. Integrated coastal management: Sustaining estuarine natural resources. *Advances in Ecological Research* 29:241-289.

Crosland, PD. 1974. *Effects of Mosquito Ditches on the Fresh Water Table in Barrier Uplands*. Masters Thesis, SUNY at Stony Brook. 41 pp.

Currin, CA, SC Wainwright, KW Able, MP Weinstein, and CM Fuller. 2003. Determination of food web support and trophic position of the mummichog, *Fundulus heteroclitus*, in New Jersey smooth cordgrass (*Spartina alterniflora*), common reed (*Phragmites australis*) and restored salt marshes. *Estuaries* 26(2B):495-510.

D'Avanzo, C. 1990. Long-term evaluation of wetland creation projects. pp. 487-496. In: Kusler, JA, and ME Kentula (eds.). *Wetland Creation and Restoration: The Status of the Science*. Island Press, Washington, DC. 594 pp.

Daiber, FC. 1986. *Conservation of Tidal Marshes*. Van Nostrand Reinhold, New York, NY. 341 pp.

Daily, GC, T. Soderqvist, S. Aniyar, K. Arrow, P. Dasgupta, PR Ehrlich, C. Folke, AM Jansson, B-O Jansson, N. Kautsky, S. Levin, J. Lubchenco, K-G Maler, D. Simpson, D. Starrett, D. Tilman, and B. Walkr. 2000. The value of nature and the nature of value. *Science* 289:396-396.

Dale, PER, and K. Hulsman. 1990. Critical review of salt marsh management methods for mosquito control. *Reviews in Aquatic Science* 3(2,3):281-311.

Davis, LV, and IE Gray. 1966. Zonal and seasonal distribution of insects in North Carolina salt marshes. *Ecological Monographs* 36(3):275-295.

Day, JW, Jr., CAS Hall, WM Kemp, and A. Yanez-Arancibia. 1989. *Estuarine Ecology*. John Wiley and Sons, New York, NY. Cited in: Deegan, LA, JE Hughes, and RA Rountree. 2000. Salt marsh ecosystem support of marine transient species. pp. 333-365. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Acadmic Publishers, Boston, MA. 875 pp.

Deegan, LA. 2002. Lessons learned: the effects of nutrient enrichment on the support of nekton by seagrass and salt marsh ecosystems. *Estuaries* 25(4B):727-742.

Deegan, LA, JE Hughes, and RA Rountree. 2000. Salt marsh ecosystem support of marine transient species. pp. 333-365. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Acadmic Publishers, Boston, MA. 875 pp.

Dowhan, J., T. Halavik, A. Milliken, A. MacLachlan, M. Caplis, K. Lima, and A. Zimba. 1997a. *Significant Habitats and Habitat Complexes of the New York Bight Watershed: Great South Bay - Complex Number 14.* United States Fish and Wildlife Service: Southern New England – New York Bight Coastal Ecosystems Program. Charlestown, Rhode Island.

Dowhan, J., T. Halavik, A. Milliken, A. MacLachlan, M. Caplis, K. Lima, and A. Zimba. 1997b. *Significant Habitats and Habitat Complexes of the New York Bight Watershed.* United States Fish and Wildlife Service: Southern New England – New York Bight Coastal Ecosystems Program. Charlestown, Rhode Island.

Dowhan, J., T. Halavik, A. Milliken, A. MacLachlan, M. Caplis, K. Lima, and A. Zimba. 1997c. *Significant Habitats and Habitat Complexes of the New York Bight Watershed: Long Pond Greenbelt - Complex Number 10.* United States Fish and Wildlife Service: Southern New England – New York Bight Coastal Ecosystems Program. Charlestown, Rhode Island.

Dowhan, J., T. Halavik, A. Milliken, A. MacLachlan, M. Caplis, K. Lima, and A. Zimba. 1997d. *Significant Habitats and Habitat Complexes of the New York Bight Watershed: Montauk Peninsula - Complex Number 7.* United States Fish and Wildlife Service: Southern New England – New York Bight Coastal Ecosystems Program. Charlestown, Rhode Island.

Dowhan, J., T. Halavik, A. Milliken, A. MacLachlan, M. Caplis, K. Lima, and A. Zimba. 1997e. *Significant Habitats and Habitat Complexes of the New York Bight Watershed: South Fork*

*Atlantic Beaches - Complex Number 11*. United States Fish and Wildlife Service: Southern New England – New York Bight Coastal Ecosystems Program. Charlestown, Rhode Island.

Downs, LL, RJ Nicholls, SP Leatherman, and J. Hautzenroder. 1994. Historic evolution of a marsh island: Bloodsworth Island, Maryland. *Journal of Coastal Research* 10(4):1031-1044.

Dreyer, GD, and WA Niering. 1995. *Tidal Marshes of Long Island Sound: Ecology, History, and Restoration*. The Connecticut College Arboretum, No. 34.

Edinger, GJ, DJ Evans, S. Gebauer, TG Howard, DM Hunt, and AM Olivero (eds.). 2002. *Ecological Communities of New York State*. 2nd Ed. (A revised and expanded edition of Carol Reschke's Ecological Communities of New York State, draft for review). New York State Department of Environmental Conservation New York Natural Heritage Program, Albany, NY.

Edwards, KR, and CE Profitt. 2003. Comparison of wetland structural characteristics between created and natural salt marshes in southwest Louisiana, USA. *Wetlands* 23(2):344-356.

Erwin, RM, JS Hatfield, MA Howe, and SS Klugman. 1994. Waterbird use of saltmarsh ponds created for Open Marsh Water Management. *Wildlife Management* 58(3):516-524.

Fell, PE, RS Warren, and WA Niering. 2000. Restoration of salt and brackish tidelands in southern new England. pp. 845-858. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Acadmic Publishers, Boston, MA. 875 pp.

Feinberg, JA, and RL Burke. 2003. Nesting ecology and predation of diamondback terrapins, *Malaclemys terrapin*, at Gateway National Recreation Area, New York. *Journal of Herpetology* 37(3):517-526.

Ferrigno, F. 1970. Preliminary effects of open marsh water management on the vegetation and organisms of the salt marsh. *Proceedings of the New Jersey Mosquito Extermination Association* 57:79-94.

Ferrigno, F., and DM Jobbins. 1968. Open Marsh Water Management. *Proceedings of the New Jersey Mosquito Extermination Association* 55:104-115.

Ferrigno, F., P. Slavin, and DM Jobbins. 1975. Saltmarsh water management for mosquito control. *Proceedings of the New Jersey Mosquito Control Association* 62:30-38.

Foley, JA, R. DeFries, GP Asner, C. Barford, G. Bonan, SR Carpenter, FS Chapin, MT Coe, GC Dailey, HK Gibbs, JH Helkowski, T. Holloway, EA Howard, CJ Kucharik, C. Monfreda, JA Patz, IC Prentice, N. Ramankutty, and PK Snyder. 2005. Global consequences of land use. *Science* 309:570-574.

Freeze, RA, and JA Cherry. 1979. *Groundwater*. Prentice-Hall, Englewood, NJ. 604 pp.

Frey, RW, and PB Basan. 1985. Coastal salt marshes. pp. 225-301. In: Davis, RA (ed.). *Coastal Sedimentary Environments*. 2nd Ed. Springer-Verlag, New York, NY. 716 pp.

Gerberich, JB. 1985. *Update of Annotated Bibliography of Papers Related to Controlling Mosquitos by the Use of Fish for the Years 1965-1981*. WHO/VBC85.917, World Health Organization, Geneva, SZ. 34 pp.

Glasgow, RD. 1938. Mosquitoes and wild life as interrelated problems in human ecology. *New York State Museum Bulletin* 316:7-20.

Grant, GS, and WW Kirby-Smith. 1998. The effect of Open marsh Water Management on summer bird populations on Topsail island, North Carolina. *Estuaries* 21(2):361-363.

Greenlaw, JS. 1983. Microgeographic distribution of breeding seaside sparrows on New York salt marshes. pp. 99-114. In: Quay, TL, JB Funderbburg, Jr., DS Lee, EF Potter, and CS Robbins (eds.). *The Seaside Sparrow: Its Biology and Management*. Occasional Papers of the North Carolina Biological Survey, 1983-5. 174 pp.

Greenlaw, JS. 1992. Seaside sparrow: *Ammodramus maritimus*. pp. 211-232. In: Schneider, KJ, and DM Pence (eds.). *Migratory Nongame Birds of Management Concern in the Northeast*. USFWS Region 5, Newton Corner, MA. 400 pp.

Guirgis, S. Undated. *The Possible Effect of Open Marsh Water Management on the Mosquito Population of Seatuck National Wildlife Refuge, Islip, Suffolk County, New York*. Seatuck Foundation, Islip, New York. 3 pp. + tables and figures.

Haas, R. and R. Pal. 1984. Mosquito larvivorous fishes. *Bulletin of the Entomological Society of America* 30(1):17-25.

Haines, EB. 1979. Interactions between Georgia salt marshes and coastal waters: a changing paradigm. pp. 35-46. In: Livingston, RJ (ed). *Ecological Processes in Coastal and Marine Systems*. Plenum Press, New York, NY. 548 pp.

Halpin, PM. 1997. Habitat use patterns of the mummichog, *Fundulus heteroclitus*, in New England. I. Intramarsh variation. *Estuaries* 20(3):618-625.

Harper, RM. 1918. Some dynamic studies of Long Island vegetation. *The Plant World* 21(2):38-46.

Harrington, RW, and ES Harrington. 1961. Food selection among fishes invading a high subtropical salt marsh: from onset of flooding through the progress of a mosquito brood. *Ecology* 42(4):646-666.

Havens, KJ, H. Berquist, and WI Priest, III. 2003. Common reed grass, *Phragmites australis*, expansion into constructed wetlands: are we mortgaging our wetlands future? *Estuaries* 26(2B):417-422.

Hellings, SE, and JL Gallagher. 1992. The effects of salinity and flooding on *Phragmites australis*. *Journal of Applied Ecology* 29:41-49.

Hettler, WF, Jr. 1989. Nekton use of regularly-flooded salt marsh cordgrass habitat in North Carolina, USA. *Marine Ecology Progress Series* 56:111-118.

Heusser, LE, CJ Heusser, and D. Weiss. 1975. Man's influence on the development of the estuarine marsh, Flax Pond, Long Island, New York. *Bulletin of the Torrey Botanical Club* 102(2)61-66.

Hobbie, JE (Ed.). 2000. *Estuarine Science: A Synthetic Approach to Research and Practice*. Island Press, Washington, DC. 539 pp.

Holst, L., R. Rozsa, L. Benoit, S. Jacobson, and C. Rilling. 2003. *Long Island Sound Habitat Restoration Initiative, Section 2: Freshwater Wetlands*. Long Island Sound Study. Stamford, CT. 19 pp.

Hopkinson, CS. 1985. Shallow water benthic and pelagic metabolism: evidence for heterotrophy in the nearshore. *Marine Biology* 87:19-32.

Howes, BL, RW Howarth, JM Teal, and I. Valiela. 1981. Oxidation-reduction potentials in a salt marsh: spatial patterns and interactions with primary production. *Limnology and Oceanography* 26(2):350-360.

Hruby, T. 1990. *Long Island Region Tidal Wetlands Management Manual: Part III: Management Plan Development*. Seatuck Foundation, Islip, NY. 42 pp.

Hruby, T., and WG Montgomery. 1985. *Open Marsh Water Management for Open Tidal Marshes in the Northeast: A Manual of Methods*. Massachusetts Audubon Society, Lincoln, MA. Paged in sections.

Hruby, T., WG Montgomery, RA Lent, and N. Dobson. 1985. Open marsh water management in Massachusetts: adapting the technique to local conditions and its impact on mosquito larvae during the first season. *Journal of the American Mosquito Control Association* 1(1):85-88.

Hruby, T, Ninivaggi, D., DP Cowan, A. Dulcey-Ortiz, and R. lent. 1988. *Site Plan for Open Marsh Management: Mott Lane/Fireplace Neck Marsh, Town of Brookhaven, New York*. Seatuck Research Program, Cornell Laboratory of Ornithology, Islip, NY. 6 pp.

James-Pirri, M-J. 1998. Mosquito Beach salt marsh OMWM restoration. *Northeastern Mosquito Control Association*, December.

James-Pirri, M-J, RM Erwin, and DJ Prosser. 2003. *Data Report for 2001 & 2002, US Fish and Wildlife Service (Region V5) Salt Marsh Study*. US Geological Survey, University of Rhode Island, and US Fish and Wildlife Service. 150 pp.

James-Pirri, M-J, CT Roman, and RM Erwin. 2002. *Data Report for the Year 1 (2001) US Fish and Wildlife Service (Region 5) Salt Marsh Study*. US Geological Survey, Narragansett, RI. 62 pp.

James-Pirri, M-J, CT Roman, and RM Erwin. 2001. *Field Methods Manual: US Fish and Wildlife Service (Region 5) Salt Marsh Study*. US Geological Survey , Narragansett, RI. 62 pp.

Jordan, TE, and I.,Valiela, 1982. A nitrogen budget of the ribbed mussel, *Geukensia demissa*, and its significance in nitrogen flow in a New England salt marsh. *Limnology and Oceanography* 27(1):75-90.

Kale, HW. 1965. *Ecology and Bioenergetics of the Long-billed Marsh Wren in Georgia Salt Marshes*. Publication Number 5 of the Nuttall Ornithology Club. 142 pp.

Kale, HW. 1968. The relationship of purple martins to mosquito control. *Auk* 85(4):654-661.

Kaplan, W., I. Valiela, and JM Teal. 1979. Denitrification in a salt marsh ecosystem. *Limnology and Oceanography* 24(4):726-734.

Kennish, MJ. 2001. Coastal salt marsh systems in the U.S.: a review of anthropogenic impacts. *Journal of Coastal Research* 17(3):731-748.

Kessler, CW. 2002. *Flanders Wetland Complex Saltmarsh Restoration – Progress Report, Year One, February 2002*. Ducks Unlimited, Stony Brook, NY. Unpaged.

Knieb, RT. 1984. Patterns in the utilization of the intertidal salt marsh by larvae and juveniles of *Fundulus heteroclitus* (Linnaeus) and *Fundulus luciae* (Baird). *Journal of Experimental Marine Biology and Ecology* 83:41-51.

Knieb, RT. 1997. The role of tidal marshes in the ecology of estuarine nekton. *Oceanography and Marine Review* 35:163-220.

Kneib, RT. 2000. Salt marsh ecoscapes and production transfers by estuarine nekton in the southeastern United States. pp. 267-291. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Acadmic Publishers, Boston, MA. 875 pp.

Knieb, RT, and SL Wagner. 1994. Nekton use of vegetated marsh habitats at different stages of tidal inundation. *Marine Ecology Progress Series* 106:227-238.

Kreeger, DA. 1988. .Utilization of cellulosic detritus by subtidal and intertidal populations of the mussel, *Geukensia demissa*. *American Zoologist* 28(4):A183-A193.

Kreeger, DA, and RIE Newell. 1996. Ingestion and assimilation of carbon from cellulolytic bacteria and heterotrophic flagellates by the mussels *Geukensia demissa* and *Mytilus edulis*. *Aquatic Microbial Ecology* 11: 205-214.

Kreeger, DA, and RIE Newell. 2000. Trophic complexity between producers and invertebrate consumers in salt marshes. pp. 187-220. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Acadmic Publishers, Boston, MA. 875 pp.

Kruczynski, WL and BF Ruth. 1997. Fishes and invertebrates. pp. 131-173. In: Coutass, CL, and Y Hsieh (eds.). *Ecology and Management of Tidal Marshes: A Model from the Gulf of Mexico*. St. Lucie Press, Delray Beach, FL.

Kumar, A. 1984. On the life history of *Pantala flavescens* (Libellulidae:Odonata). *Annals of Entomology* 2(1):43-50.

Kunz, TH. 1988. Methods of assessing the availability of prey to insectivorous bats. pp. 191-210. In: Kunz, TH (ed.). *Ecological and Behavioral Methods for the Study of Bats*. Smithsonian Institution Press, Washington, DC. 533 pp.

Lamont, E. 1997. Early collections of Phragmites from Long Island, New York. *Long Island Botanical Society Newsletter* 7(2):9-10.

Langdon, CJ, and RIE Newell. 1990. Utilization of detritus and bacteria as found sources by two bivalve suspension- feeders, the oyster *Crassostrea virginica* and the mussel *Geukensia demissa*. *Marine Ecology Progress Service* 58: 299- 310.

Lathrop, RG, MP Cole, and RD Showalter. 2000. Quantifying the habitat structure and spatial pattern of New Jersey (U.S.A.) salt marshes under different habitat regimes. *Wetlands Ecology and Management* 8:163-172.

Lathrop, RG, L. Windham, and P. Montesano. 2003. Does *Phragmites* expansion alter the structure and function of marsh landscapes? Patterns and processes revealed. *Estuaries* 26(2B):423-435.

Lent, RA, T. Hruby, DP Cowan, and TS Litwin. 1990. *Open Marsh Water Management on Great South Bay, Islip, New York*. Seatuck Foundation, Islip, NY. 102 pp.

Leonard, LA, and ME Luther. 1995. Flow hydrodynamics in tidal marsh canopies. *Limnology and Oceanography* 40(8):1474-1484.

Lesser, CR. Undated. *Open marsh Management: A Source Reduction Technique for Mosquito Control*. Delaware Department of Natural Resources. www.dnrec.state.de/fw/mosquito/final%20Draft%202%20of%20OMWMArticleApril.pdf.

Lesser, CR, RM Altman, and LF George. 1978. Open Marsh Management in Maryland. *Proceedings of the New Jersey Extermination Association* 65:41-46.

Lesser, CR, FJ Murphy, and RW Lake. 1976. Some effects of grid system mosquito control ditching on salt marsh biota in Delaware. *Mosquito News* 36:69-77.

Lesser, CR, and DE Saveikis. 1979. *A Study of the Impacts of a Mosquito Control Integrated Pest Management Program on Selected Parameters of the Ecology of Chesapeake Bay High Marsh Communities in Maryland*. Maryland Department of Agriculture, Annapolis, MD.

Levine, JM, JS Brewer, and MD Bertness. 1998. Nutrients, competition and plant zonation in a New England salt marsh. *Journal of Ecology* 86:285-292.

Lynch, EA, and K. Salstonstall. 2002. Paleoecological and genetic analyses provide evidence for recent colonization of native *Phragmites australis* populations in a Lake Superior wetland. *Wetlands* 22(4):637-646.

MacArthur, RH. 1965. Patterns of species diversity. *Biological Review of the Cambridge Philosophical Society* 40:510-533.

MacDonald, D., and G. Edinger. 2000. *Identification of Reference Wetlands on Long Island, New York*. New York Natural Heritage Program, Latham, NY. 106 pp. + appendices

MacIntyre, HL and JJ Cullen. 1995. Fine-scale vertical resolution of chlorophyll and photosynthetic parameters in shallow-water benthos. *Marine Ecology Progress Series* 122:227-237.

Malakoff, D. 1998. Restored wetlands flunk real-world test. *Science* 280:371-372.

Marks, M., B. Lapin, and J. Randall. 1994. *Phragmites autralis* (*P. communis*): threats, management, monitoring. *Natural Areas Journal* 14:285-294.

MacIntyre, HL, RJ Geider, and DC Miller. 1996. Microphytobenthos: the ecological role of the "Secret Garden" of unvegetated, shallow-water marine habitats. I. Distribution, abundance and primary production. *Estuaries* 19:186-201.

McAvoy, G. 2004. Bats eat mosquitoes as well as numerous garden pests. http://hendry.ifas.ufl.edu/HCHortNew_Bats.htm

Melville, AJ, and RM Connolly. 2003. Spatial analysis of stable isotope data to determine primary sources of nutrition for fish. *Oecologia* 136(4):499-507.

Mendelssohn, IA. 1979. Nitrogen metabolism in the height forms of *Spartina alterniflora* in North Carolina. *Ecology* 60(3):574-584.

Merriam, TL. 1983. Food habits of nestling seaside sparrows in unaltered and ditched salt marshes on Long Island, New York. pp. 115-122. In: Quay, TL, JB Funderbburg, Jr., DS Lee, EF Potter, and CS Robbins (eds.). *The Seaside Sparrow: Its Biology and Management*. Occasional Papers of the North Carolina Biological Survey, 1983-5. 174 pp.

Metzler, KJ, and RW Tiner. 1992. *Wetlands of Connecticut*. Report of Investigations No. 13, State Geological and Natural History Survey of Connecticut. Hartford, CT. 115 pp.

Meyerson, LA, KA Vogt, and RH Chalmers. 2000. Linking the success of *Phragmites* to the alteration of ecosystem nutrient cycles. pp. 827-844. In: Weinstein, MP, and DA

Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Acadmic Publishers, Boston, MA. 875 pp.

Middleton, B. 1999. *Wetland Restoration, Flood Pulsing, and Disturbance Dynamics*. John Wiley and Sons, New York, NY. 388 pp.

Miller, JM, and ML Dunn. 1980. Feeding strategies and patterns of movement in juvenile estuarine fishes. pp. 437-448. In: Kennedy, VS (ed.). *Estuarine Perspectives*. Academic Press, New York, NY. 533 pp.

Miller, WR, and FE Egler. 1950. Vegetation of the Wequetequock-Pawcatuck tidal marshes, Connecticut. *Ecological Monographs* 20:143-172.

Miller, DC, RJ Geider, and HL Macintyre. 1996. Microphytobenthos: the ecological role of the "Secret Garden" of unvegetated, shallow-water marine habitats, role in sediment stability and shallow water food webs. *Estuaries* 19:202- 212.

Minello, TJ, and RJ Zimmerman. 1992. Utilization of natural and transplanted Texas salt marshes by fish and decapod crustaceans. *Marine Ecology Progress Series* 90:273-285.

Minello, TJ, RJ Zimmerman, and RE Medina. 1994. The importance of edge for natant macrofauna in a created salt marsh. *Wetlands* 14:184-198.

Mitsch, WJ. 2000. Self-design applied to coastal restoration, and application of ecological engineering. pp. 554-564. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Acadmic Publishers, Boston, MA. 875 pp.

Mitsch, WJ, and JG Gosselink. 2000. *Wetlands*. 3rd Ed. John Wiley and Sons, New York, NY. 920 pp.

Mitsch, WJ, X. Wu, RW Nairn, PE Weihe, N. Wang, R. Deal, and CE Boucher. 1998. Creating and restoring wetlands: a whole ecosystem experiment in self-design. *BioScience* 48(12)1019-1030.

Montague, CL, SM Bunker, EB Haines, ML Pace, and RL Wetzel. 1981. Aquatic macroconsumers. pp. 69-85. In: Pomeroy, LR, and RG Wiegert (eds.). *The Ecology of a Salt Marsh*. Springer-Verlag, New York, NY. 271 pp.

Montague, CL, AV Zale, and HF Percival. 1987. Ecological effects of impoundments: a review. *Environmental Management* 11(6):743-756.

Montgomery, WG. 1998. Rumney Marsh, Park Avenue restorations project. *Northeastern Mosquito Control Association*, December. pp. 10-11.

Morreale, SJ. 1992. *The Status and Population Ecology of the Diamondback Terrapin, Malaclemys terrapin, in New York Waters*. OKEANOS Ocean Research Foundation, Inc. Riverhead, NY. 77 pp.

Murphy, M. 1989. Dr. Campbell's "Malaria-eradicating, guano-producing bat roosts." *Bats* 7(2):10-13.

NJDEP. 1980. *Standards for Open Marsh Water Management (OMWM).* New Jersey Department of Environmental Protection. 3 pp.

NYSDEC. 2004a. *Freshwater Wetlands Program*. September 9, 2004. http://www.dec.state.ny.us/website/dfwmr/habitat/fwwprog.htm

NYSDEC. 2004b. *Wetland Functions and Values*. September 9, 2004. http://www.dec.state.ny.us/website/dfwmr/habitat/fwwprog2.htm

NYSDEC. 2004c. *Freshwater Wetlands Status and Trends.* September 9, 2004. http://www.dec.state.ny.us/website/dfwmr/habitat/fwwprog3.htm

NYSDEC. 2004d. *Programs to Conserve Wetlands.* September 14, 2004. http://www.dec.state.ny.us/website/dfwmr/habitat/fwwprog4.htm

NYSDEC. 2003. *New York State Amphibian and Reptile Atlas 1990-1998 Data: Interim Report.* (Maps.) http://www.dec.state.ny.us/website/dfwmr/wildlife/herp /turtles.html

NYSDEC. 2001. *New York State Stormwater Management Design Manual*. New York State Department of Environmental Conservation, Albany, NY. Paged in sections.

NYSDEC and USFWS. 1998. *Marine Turtles, Diamond Back Terrapin, Mud Turtles, and Seals*. South Shore Estuary Reserve Technical Report Series. Farmingdale, NY.

National Research Council. 1992. *Restoration of Aquatic Ecosystems*. National Academy Press, Washington, DC. 552 pp.

Native America. 2004. Hauppauge Springs. September 2, 2004. http://www.nativeamerica.com/preservation.html

New Hampshire Coastal Program. 2004. *New Hampshire Salt Marsh restoration: Fairhill Marsh, Rye, NH.* New Hampshire Coastal Program, Portsmouth, NH. Pamphlet.

Newell, SY. 2003. Fungal content and activities in standing-decaying leaf blades of plants of the Georgia Coastal Ecosystems research area. *Aquatic Microbial Ecology* 32(1):95-103.

Newell, SY. 2001. Fungal biomass and productivity. *Methods in Microbiology* 30:357-372.

Niedowski, N. 2000. *New York State Salt Marsh Restoration and Monitoring Guidelines*. NYS Department of State, Albany, NY, and NYS Department of Environmental Conservation, East Setauket, NY. 135 pp.

Niering, WA. 1990. Vegetation dynamics in relation to wetland creation. pp. 479-486. In: Kusler, JA, and ME Kentula (eds.). *Wetland Creation and Restoration: The Status of the Science*. Island Press, Washington, DC. 594 pp.

Niering, WA, and RS Warren. 1980. Vegetation patterns and processes in New England salt marshes. *BioScience* 30:301-307.

Newell, RC. 1965. The role of detritus in the nutrition of two marine deposit-feeders, the prosobranch *Hydrobia ulvae* and the bivalve *Macoma bathica*. *Proceedings of the Zoological Society of London* 144: 25-45.

Newell, SY, and D. Porter. 2000. Microbial secondary production from salt marsh-grass shoots, and its known and potential fate. pp. 159-185. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Acadmic Publishers, Boston, MA. 875 pp.

Nixon, SW. 1982. *The Ecology of New England High Salt Marshes: A Community Profile*. FWS/OBS-81/55, US Fish and Wildlife Service, Washington, DC. 70 pp.

Nixon, SW. 1980. *Between Coastal Marshes and Coastal Waters – a Review of Twenty Years of Speculation and Research on the Role of Salt Marshes in Estuarine Productivity and Water Chemistry*. Hamilton, P. and McDonald KB, eds. Estuarine and Wetland Processes with an Emphasis on Modeling 653 pp.

Nuttle, WK. 1988. Salt marsh hydrology: implications for biogeochemical fluxes to the atmosphere and estuaries. *Global Biogeochemical Cycles* 2(2):91-114.

O'Connor, JS, and OW Terry. 1972. *The Marine Wetlands of Nassau and Suffolk Counties, new York*. SUNY at Stony Brook. 99 pp.

Odum, EP. 2000. Tidal marshes as outwelling/pulsing systems. pp. 3-7. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Acadmic Publishers, Boston, MA. 875 pp.

Odum, EP. 1979. The status of three ecosystem-level hypothesis regarding salt marsh estuaries: tidal subsidy, outwelling and detritus-based food chains. *The Fifth Biennial International Estuarine Research Conference Abstracts, Jekyll Island, GA*. Oct. 7-12.

Odum, EP. 1961. The role of salt marshes. *New York Conservationist*, June-July, p. 12.

Odum, EP. 1961. The role of tidal marshes in estuarine production. *New York State Conservation* 15(6):12-15.

Odum, EP, and AA de la Cruz. 1967. Particulate organic detritus in a Georgia salt marsh estuarine ecosystem. pp. 383-388. In: Lauff, GH (ed.). *Estuaries*. Pub. 83, American Association for the Advancement of Science.

Odum, WE. 1988. Comparative ecology of tidal freshwater and salt marshes. *Annual Review of Ecology and Systematics* 19:147-176.

Odum, WE, JS Fisher, and JC Pickral. 1979. Factors controlling the flux of particulate organic carbon from estuarine wetlands. pp. 69-80. In: Livingston, RJ (ed.). *Ecological Processes in Coastal and Marine Systems*. Plenum Press, New York. 548 pp.

Orson, RA. 1999. A paleoecological assessment of *Phragmites australis* in New England tidal marshes: changes in plant community structure during the last few millennia. *Biological Invasions* 1:149-158.

Orson, RA, RS Warren, and WA Niering. 1987. Development of a tidal marsh in a New England river valley. *Estuaries* 10(1):20-27.

Pennings, SC, and MD Bertness. 1999. Using latitudinal variation to examine effects of climate on coastal salt marsh patterns and process. *Wetlands Biogeochemistry* 3:100-111.

Pennings, SC, LE Stanton, and JS Brewer. 2002. Nutrient effects on the composition of salt marsh plant communities along the southern Atlantic and Gulf coasts of the United States. *Estuaries* 25(6A):1164-1173.

Penny, L. 1977. Phragmites on the South Fork of Long Island. *Long Island Botanical Society Newsletter* 7(2):12-13.

Peterson, BJ, RW Howarth, WJ Pfeiffer and RG Wiegert. 1981. Grazers on spartina and their predators. pp. 87-112. In: Pomeroy, LR, and RG Wiegert (eds.). *The Ecology of a Salt Marsh*. Springer-Verlag, New York, NY. 271 pp.

Peterson, GW, and RE Turner. 1994. The value of salt marsh edge vs. interior as a habitat for fish and decapod crustaceans in a Louisiana tidal marsh. *Estuaries* 18:235-262.

Pomeroy, LR, WM Darley, EL Dunn, JL Gallagher, EB Haines, and DM Whitney. 1981. Primary production. pp. 39-67. In: Pomeroy, LR, and RG Wiegert (eds.). *The Ecology of a Salt Marsh*. Springer-Verlag, New York, NY. 271 pp.

Pomeroy, LR, and J. Imberger. 1981. The physical and chemical environment. pp. 21-36. In: Pomeroy, LR, and RG Wiegert (eds.). *The Ecology of a Salt Marsh*. Springer-Verlag, New York, NY. 271 pp.

Pomeroy, LR, RE Johannes, EP Odum, and B. Roffman. 1967. The phosphorus and zinc cycles and productivity of a salt marsh. In: Nelson, DJ, and FC Evans (ed.). *Symposium on Radioecology: Proceedings of the Second National Symposium*. Ann Arbor, MI, May 15-17.

Post, W. 1970. 46. Salt marsh. *Audubon Field Notes*, December. pp. 771-772.

Post, W., and JS Greenlaw. 2000. The present and future of the Cape Sable seaside sparrow. *Florida Field Natuarlist* 28(3):93-110.

Post, W., and JS Greenlaw. 1975. Seaside sparrow displays: their function in social organization and habitat. *The Auk* 92:461-492.

Price, MH. 1938. New developments in mosquito control in Rhode Island. *Proceedings of the New Jersey Extermination Association* 25:111-115.

Prinslow, TW, I.Valiela, and JM Teal. 1974. The effects of detritus and ration size on the growth of *Fundulus heteroclitus* (L.). *Journal of Experimental Marine Biology and Ecology* 16:1-10.

Provost, MW. 1977. Source-reduction in mosquito control: past and future. *Mosquito News* 37(4):689-698.

Racey, PA, and SM Swift. 1985. Feeding ecology of *Pipistrellus pipistrellus* (Chiroptera: Vespertilionidae) during pregnancy and lactation. I. Foraging Behaviour. *Journal of Animal Ecology* 54:205-216.

Redfield, AC. 1972. Development of a New England salt marsh. *Ecological Monographs* 42(2):1-23.

Redfield, AC. 1965. Ontogeny of a salt marsh estuary. *Science* 147:50-55.

Reimold, RJ. 1977. Managals and salt marshes of the eastern United States. In: Chapman, VJ (ed.). *Wet Coastal Ecosystems.* Elseveir Scientific Publishing Company, Amsterdam, ND.

Reinert, SE, FC Golet, and WR DeRagon. 1981. Avian use of ditched and unditched salt marshes in southeastern new England. *Transactions of the Northeastern Mosquito Control Association* 17:1-23.

Reinert, SE, and MJ Mello. 1995. Avian community structure and habitat use in a southern New England estuary. *Wetlands* 15(1):9-19.

Ribelin, BW, and AW Collier. 1979. Ecological considerations of detrital aggregates in the salt marsh. pp. 47-68. In: Livingston, RJ (ed.). *Ecological Processes in Coastal and Marine Systems.* Plenum Press, New York,NY. 548 pp.

Richards, AG, Jr. 1938. Mosquitoes and mosquito control on Long Island, New York, with particular reference to the salt marsh problem. *New York State Museum Bulletin* 316:85-172.

Rockel, EG. 1969. Marsh physiography: influence on the distribution of organisms. *Proceedings of the New Jersey Mosquito Extermination Association* 56:102-116.

Roman, CT. 1998. *Ecosystem Response of Salt Marshes to Open Marsh Water Management (OMWM): Experiments at Rachel Carson National Wildlife Refuge (Maine).* Study Proposal to US Fish and Wildlife Service Region 5. 19 pp.

Roman, CT, WA Niering, and RS Warren. 1984. Salt marsh vegetation changes in response to tidal restrictions. *Environmental Management* 8:141-150.

Roman, CT, KB Raposa, SC Adamowicz, MJ James-Pirri, and JG Catena. 2002. Quantifying vegetation and nekton response to tidal restoration in a New England marsh. *Restoration Ecology* 10(3):450-460.

Romanowski, M. 1991. A five-year study of the effects of OMWM on meadow vole populations in Ocean County. *Proceedings of the New Jersey Mosquito Control Association* 78:101-107.

Rozas, LP. 1995. Hydroperiod and its influence on nekton use of the salt marsh: a pulsing system. *Estuaries* 18:579-590.

Rozas, LP, and MW LaSalle. 1990. A comparison of the diets of Gulf killifish, *Fundulus grandis* Baird and Girard, entering and leaving a Mississippi brackish marsh. *Estuaries* 13(3):332-336.

Rozsa, R. 1995. Tidal wetland restoration in Connecticut. Pp. 51-65. In: Dreyer, GD, and WA Niering (eds.). *Tidal marshes of Long Island Sound, Ecology, History and Restoration*. Connecticut College Arboretum Bulletin No. 34. 72 pp.

Salstonstall, K. 2002. Cryptic invasion by a non-native genotype of the common reed, *Phragmites australis*, into North America. *Proceedings of the National Academy of Sciences* 99:2445-2449.

Sanzone, S., and A. McElroy (eds.). 1998. *Ecological Impacts and Evaluation Criteria for the use of Structures in Marsh Management*. EPA Science Advisory Board, Washington DC. 53 pp.

Schubauer, JP, and CS Hopkinson. 1984. Above- and belowground emergent macrophyte production and turnover in a coastal marsh ecosystem, Georgia. *Limnology and Oceanography* 29(5):1052-1065.

Shelter Island. 2004. *Mashomack Preserve.* September 2, 2004. http://www.shelter-island.org/mashomack.html

Shisler, JK. 1990. Creation and restoration of coastal wetlands of the northeastern United States. pp. 143-163. In: Kusler, JA, and ME Kentula (eds.). *Wetland Creation and Restoration: The Status of the Science*. Island Press, Washington, DC. 594 pp.

Shisler, JK. 1978. Water management methods being utilized in coastal marshes to control mosquito populations. *Proceedings of the New Jersey Mosquito Control Association* 65:59-66.

Shisler, JK, and DM Jobbins. 1977a. Salt marsh productivity as affected by the selective ditching technique, open marsh water management. *Mosquito News* 37:631-636.

Shisler, JK, and DM Jobbins. 1977b. Tidal variations in the movement of organic carbon in salt marshes in New Jersey. *Marine Biology* 40:127-134.

Shisler, JK, F. Lesser, and T. Candeletti. 1979. An approach to the evaluation of temporary versus permanent measures in salt marsh mosquito control operations. *Mosquito News* 39(4):776-780.

Sibley, DA. 2001. *The Sibley Guide to Bird Life and Behavior*. Alfred A. Knopf, Inc., New York, NY.

Silsby, J. 2001. *Dragonflies of the World*. Smithsonian Institution Press, Washington, DC.

Sinicrope, TL, PG Hine, RS Warren, and WA Niering. 1990. Restoration of an impounded salt marsh in New England. *Estuaries* 13(1):25-30.

Smith, JB. 1904. *Report of the NJ State Agricultural Experiment Station upon the Mosquitoes Occuring within the State, Their Habits, Life History, etc.* MacCrellish & Quigley, Trenton, NJ. 482 pp.

Smith, KJ, GL Taghon, and KW Able. 2000. Trophic linkages in marshes: ontogenetic changes in diet for young-of-the-year mummichog, *Fundulus heteroclitus*. pp. 221-236. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Academic Publishers, Boston, MA. 875 pp.

Sperry, TG. 1992. *Continued Investigation of Potential Locations that Could Benefit from the Practice of Open Marsh Water Management: Studies at Fireplace Neck Marsh, Town of Brookhaven, 1991*. Suffolk County Bureau of Vector Control. Unpaged.

Spinner, GP. 1969. *A Plan for the Marine Resources of the Atlantic Coastal Zone*. American Geographical Society. 80 pp.

Stearns, LA, D. MacCreary, and FC Daigh. 1939. Water and plant requirements of the muskrat on a Delaware tide watermarsh. *Proceedings of the New Jersey Mosquito Extermination Association* 26:212-221.

Steever, EZ, RS Warren, and WA Niering. 1976. Tidal energy subsidy and standing crop production of *Spartina alterniflora*. *Estuarine, Coastal and Shelf Science* 4:473-478.

Stevenson, JC, LG Ward, and MS Kearney. 1986. Vertical accretion in marshes with varying rates of sea-level rise. pp. 241-259. In: Wolfe, DA (ed.). *Estuarine Variability.* Academic Press, New York, NY. 509 pp.

Stevenson, JC, RE Rooth, MS Kearney, and KL Sundberg. 2000. The health and long term stability or natural and restored marshes in Chesapeake Bay. pp. 709-735. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Academic Publishers, Boston, MA. 875 pp.

Stewart, PG, and L Springer-Rushia. 1998. *A Field Guide to Long Island's Freshwater Wetlands*. The Museum of Long Island Natural Sciences, State University of New York at Stony Brook. Stony Brook, New York. 90 pp.

Stolzenbach, KD, KA Newman, and CS Wong. 1992. Aggregation of fine particles at the sediment-water interface. *Journal of Geophysical Research* 97(C11):17889-17898.

Storer, TT. 1926. Bats, bat towers and mosquitoes. *Journal of Mammology* 7:85-90.

Sullivan, MJ, and CA Moncreiff. 1990. Edaphic algae are an important component of salt marsh food-webs - evidence from multiple stable isotope analyses. *Marine Ecology Progress Series* 62(1-2):149-159.

Sullivan, MJ, and CA Moncrieff. 1988. Primary production of edaphic algal communities in a Mississippi salt marsh. *Journal of Phycology* 24:49- 58.

Sullivan, MJ, and CA Currin. 2000. Community structure and functional dynamics of benthic macroalgae in salt marshes. pp. 81-106. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Acadmic Publishers, Boston, MA. 875 pp.

Swift, SM, PA Racey, and MI Avery. 1985. Feeding ecology of *Pipistrellus pipistrellus* (Chiroptera: Vespertilionidae) during pregnancy and lactation. II. Diet. *Journal of Animal Ecology* 54:217-225.

Talbot, CW, and KW Able. 1984. Composition and distribution of larval fishes in New Jersey high marshes. *Estuaries* 7:434-443.

Talbot, CW, KW Able, and JK Shisler. 1986. Fish species composition in New Jersey salt marshes: effects of marsh alterations for mosquito control. *Transactions of the American Fisheries Society* 115:269-278.

Taylor, J. 1998. *Guidance for Meeting US Fish and Wildlife Service Trust Resource Needs When Conducting Coastal Marsh Management for Mosquito Control on Region 5 National Wildlife Refuges*. US Fish and Wildlife Service, Region 5. 27 pp.

Taylor, N. 1938. A preliminary report on the salt marsh vegetation of Long Island, New York. *New York State Museum Bulletin* 316:21-84.

Teal, JM. 1986. *The Ecology of Regularly Flooded Salt Marshes of New England: A Community Profile*. Biological Report 85(7.4), US Fish and Wildlife Service, Washington, DC. 61 pp.

Teal, JM. 1962. Energy-flow in the salt-marsh ecosystem of Georgia. Ecology 43(4):614-624.

Teal, J. and BL Howes. 2000. Salt marsh values: retrospection from the end of the century. pp. 9-19. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Academic Publishers, Boston, MA. 875 pp.

Theodose, TA, and JB Roths. 1999. Variation in the nutrient availability and plant species diversity across forb and graminoid zones of a northern New England salt marsh. *Plant Ecology* 143:219-228.

Turner, RE. 1977. Intertidal vegetation and commercial yields of penaeid shrimp. *Transactions of the American Fisheries Society* 106:411-416.

Turrell, MJ, DJ Dohm, MR Sardelis, ML O'Guinn, TG Andreadis, and JA Blow. 2005. An update on the potential of North American mosquitoes (Diptera:Culicidae) to transmit West Nile virus. *Journal of Medical Entomology* 42(1):57-62.

USEPA. 2001. *Functions and Values of Wetlands.* EPA 843-F-01-002c. US Environmental Protection Agency, Washington, DC. 2 pp.

USFWS. 1999. *Concerns and Issues about Mosquito Control on the National Wildlife Refuges in the Northeast*. US Fish and Wildlife Service, Region V. 53 pp.

USFWS. 1998. *The Peconic Watershed – Recent Trends in Wetlands and Their Buffers.* National Wetlands Inventory Program, Northeast Region. Draft for review/comment. 50 pp.

USFWS. 1997. *Significant Habitats and Habitat Complexes of the New York Bight Watershed.* New York Bight Coastal Ecosystems Program, United States Fish and Wildlife Service, Charlestown, RI.

Udell, HF, J. Zarudsky, and TE Doheny. 1969. Productivity and nutrient values of plants growing in the salt marshes of the Town of Hempstead, Long Island. *Bulletin of the Torrey Botanical Club* 96(1):42-51.

Valiela, I. 1982. Nitrogen in salt marsh ecosystems. pp. 649-678. In: Carpenter, EJ, and DG Capone (eds.). *Nitrogen in the Marine Environment*. Academic Press, New York, NY.

Valiela, I., ML Cole, J. McClelland, J. Hauxwell, J. Celebrian, and SB Joye. 2000. Role of salt marshes as part of coastal landscapes. pp. 23-38. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Acadmic Publishers, Boston, MA. 875 pp.

Valiela, I., and JM Teal. 1979. The nitrogen budget of a salt marsh ecosystem. *Nature* 280:652-656.

Valiela, I., JM Teal, and NY Persson. 1976. Production and dynamics of experimentally enriched salt marsh vegetation: belowground biomass. *Limnology and Oceanography* 21:245-252.

Valiela, I, JE Wright, JM Teal, and SB Volkmann. 1977. Growth, production, and energy transformations in the salt marsh killifish *Fundulus heteroclitus*. *Marine Biology* 40:135-144.

Virstein, RW. 1977. The importance of predation by crabs and fishes on benthic infauna of Chesapeake Bay. *Ecology* 58:1199-1277.

Wade, JL. 1966. *What You Should Know about the Purple Martin*. Trio Manufacturing Co., Griggsville, IL. (pamphlet).

Wainwright, SC, MP Weinstein, KW Able, and CA Currin. 2000. Relative importance of benthic macroalgae, phytoplankton, and the detritus of smooth cordgrass *Spartina alterniflora* and the common reed *Phragmites australis* to brackish-marsh food webs. *Marine Ecology Progress Series* 200:77-91.

Warren, RS, PE Fell, R. Rosza, AH Brawley, AC Orsted, ET Olsen, V. Swamy, and WA Niering. 2002. Salt marsh restoration in Connecticut: 20 years of science and management. *Restoration Ecology* 10(3):497-513.

Warren, RS, PE Fell, JL Grimsby, EL Buck, GC Rilling, and RA Fertik. 2001. Rates, patterns, and impacts of *Phragmites australis* expansion and effects of experimental *Phragmites* control on vegetation, macroinvertebrates, and fish within tidelands of the lower Connecticut River. *Estuaries* 24(1):90-107.

Weinstein, MP, SY Litvin, KL Bosley, CM Fuller, and SC Wainright. 2000a. The role of tidal salt marsh as an energy source for marine transient and resident finfishes: a stable isotope approach. *Transactions of the American Fisheries Society* 129(3):797-810.

Weinstein, MP, KR Philipp, and P. Goodwin. 2000b. Catastrophes, near catastrophes and the bounds of expectation: success criteria for macro-scale marsh restoration. pp. 777-804. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Academic Publishers, Boston, MA. 875 pp.

West, JM, and JB Zedlar. 2000. Marsh-creek connectivity: fish use of a tidal marsh in Southern California. *Estuaries* 23(5):699-710.

Whalley, SD, and TJ Minello. 2002. The distribution of benthic infauna of a Texas salt marsh in relation to the marsh edge. *Wetlands* 22 (4):753-766.

Whigham, DF, J. O'Neill, and M. McWethy. 1982. Ecological implications of manipulating coastal wetlands for purposes of mosquito control. pp. 459-476. In: *Wetlands, Ecology, and Management*. National Institute of Ecology and International Scientific Publications, Jaipur, India.

Whitaker, JO, Jr. 1994. Food availability and opportunistic versus selective feeding in insectivorous bats. *Bat Research* News 35(4):75-77.

Whitaker, JO, Jr. 1988. Food habits analysis of insectivorous bats. pp. 171-189. In: Kunz, TH (ed.). *Ecological and Behavioral Methods for the Study of Bats*. Smithsonian Institution Press, Washington, DC. 533 pp.

Widjeskog, L. 1994. Duck habitat and Open Marsh Water Management. *Proceedings of the New Jersey Mosquito Control Association* 81:48-51.

Wiegert, RG, and FC Evans. 1967. Investigations of secondary productivity in grasslands. In: Petrusewicz, K. (ed.). *Secondary Productivity of Terrestrial Ecosystems*. Polish Academy of Sciences, Cracow, PO.

Wiegert, RG, and BJ Freeman. 1990. *Tidal Salt Marshes of the Southeast Atlantic Coast: A Community Profile.* Biological Report 85(7.29), US Fish and Wildlife Service, Washington, DC. 69 pp.

Wiegert, RG, LR Pomeroy, and WJ Wiebe. 1981. The ecology of salt marshes: an introduction. pp. 3-19. In: Pomeroy, LR, and RG Wiegert (eds.). *The Ecology of a Salt Marsh*. Springer-Verlag, New York, NY. 271 pp.

Willard, DE, and AK Hiller. 1990. Wetland dynamics: considerations for restored and created wetlands. pp. 459- 466. In: Kusler, JA, and ME Kentula (eds.). *Wetland Creation and Restoration: The Status of the Science*. Island Press, Washington, DC. 594 pp.

Willott, E. 2004. Restoring nature, without mosquitoes? *Restoration Ecology* 12(2):147-153.

Windham, L., and LA Meyerson. 2003. Effects of common reed (*Phragmites australis*) expansions on nitrogen dynamics of tidal marshes of the Northeastern U.S. *Estuaries* 26(2B):452-464.

Witje, AHBM, and JL Gallagher. 1996a. Effect of oxygen availability and salinity on early life stages of salt marsh plants. I. Different germination strategies of *Spartina alterniflora* and *Phragmites australis* (Poaceae). *American Journal of Botany* 83(10):1337-1342.

Witje, AHBM, and JL Gallagher. 1996b. Effect of oxygen availability and salinity on early life stages of salt marsh plants. II. Early seedling development advantage of *Spartina alterniflora* and *Phragmites australis* (Poaceae). *American Journal of Botany* 83(10):1343-1350.

Wolaver, TG, RL Wetzel, JC Zieman, and KL Webb. Nutrient interactions between salt marsh, mudflats, and estuarine water. pp. 123-133. In: Kennedy, VS (ed.). *Estuarine Perspectives*. Academic Press, New York, NY. 533 pp.

Wolfe, RJ. 1996. Effects of Open Marsh Water Management on selected tidal marsh resources: a review. *Journal of the American Mosquito Control Association* 12(4):701-712.

Wolfe, RJ. 1992. A decade of Open Marsh Water Management in Delaware: reducing Aedes in the 80's. *Proceedings of the New Jersey Mosquito Control Association* 79:51-56.

Wolfe, RJ. Undated. *Enhancement of Tidal Wetlands Habitat Using Open Marsh Water Management on PRBM Hook National Wildlife Refuge*. Delaware Department of Natural Resources. Unpaged.

Wolfe, RJ, P. Capotosto, and W. Stober. Undated. *Open Marsh Water Management: A Review of System Designs and Installation Guidelines for Mosquito Control and OMWM's Integration into Wetland Habitat Management*. Connecticut Department of Environmental Protection. PowerPoint Presentation, given at Yaphank, NY, April, 2004.

Woodwell, GM, CAS Hall, DE Whitney, and RA Houghton. 1979. The Flax Pond ecosystem study: exchanges of inorganic nitrogen between an estuarine marsh and Long Island Sound. *Ecology* 60(4):695-702.

Wrenn, J. 2002. Monitoring the effects of an Open Marsh Water management project at Waterford Beach. *Northeastern Mosquito Control Association*, December. pp. 84-90.

Yozzo, DJ, and DE Smith. 1998. Composition and abundance of resident marsh-surface nekton: comparison between tidal freshwater and salt marshes in Virginia, USA. *Hydrobiologia* 362:9-19.

Zdragas, A., GC Zalides, V. Takavakoglou, S. Katsavouni, ET Anastasiadis, and K. Eskridge. 2002. The effect of environmental conditions on the ability of a constructed wetland to disinfect municipal wastewaters. *Environmental Management* 29(4):510-515.

Zedler, JB. 1980. Algal mat productivity: comparisons in a salt marsh. *Estuaries* 3(2):122-131.

Zedlar, JB, and R. Lindig-Cisneros. 2000. Functional equivalency of restored and natural salt marshes. pp. 565-582. In: Weinstein, MP, and DA Kreeger (eds.). *Concepts and Controversies in Tidal Marsh Ecology*. Kluwer Academic Publishers, Boston, MA. 875 pp.

Zheng, L., C. Chen, and H. Liu. 2003. A modeling study of the Satilla River estuary, Georgia. I. Flooding-drying process and water exchange over the salt marsh-estuary-shelf complex. *Estuaries* 26(3):651-669.

Zheng, L., RJ Stevenson, and C. Craft. 2005. Changes in benthic algal attributes during salt marsh restoration. *Wetlands* 24(2):309-323.