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Assessing Dynamic Soil Properties in Southern New England Using an Ecological Site Framework

Andrew James Paolucci
University of Rhode Island, andrew_paolucci@my.uri.edu

ASSESSING DYNAMIC SOIL PROPERTIES IN SOUTHERN NEW ENGLAND USING AN ECOLOGICAL SITE FRAMEWORK

BY

ANDREW JAMES PAOLUCCI

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ANDREW PAOLUCCI

APPROVED:

Thesis Committee:

Major Professor Mark Stolt

Serena Moseman-Valtierra

Jose A. Amador

Nasser H. Zawia
DEAN OF THE GRADUATE SCHOOL

UNIVERSITY OF RHODE ISLAND
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ABSTRACT

An ecological site is defined as a distinctive kind of land based on recurring soil, landform, geological, and climate characteristics that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its ability to respond similarly to management actions and natural disturbances. The primary objective of this study was to initiate provisional ecological site concepts for upland, riparian, salt marsh, and subaqueous soils in southern New England by comparing sites that share similar geomorphic settings, but differing soil types. For each system, I also determined how a specific disturbance or management scenario affected dynamic soil properties. In uplands, Merrimac (sandy) and Enfield (silty) soil components were compared to determine whether or not these soils are different ecological sites. My preliminary investigation showed that forest stands on these soils could be coniferous or deciduous. Therefore, within each upland soil type, three deciduous and three coniferous sites were investigated. Within the upper 50 cm, Merrimac soils averaged 61% sand, which was significantly greater than the 26% recorded for Enfield ($p<0.01$). Although this supports that these soils differ in drainage, soil texture did not seem to influence the 50 cm soil organic carbon pools between Merrimac (109 Mg C ha^{-1}) and Enfield (101 Mg C ha^{-1}; $p=0.66$). Even though the Merrimac soils are sandier and thus better drained than Enfield, the similarity in vegetation composition and tree productivity indicate that these soils have similar ecological potential. 15 years after the selective harvest of sites with either Enfield or Merrimac soils, soil carbon pools were determined to be resilient to change. I concluded that the 50% removal of overstory trees decreases carbon additions from litter by 28% ($p=0.036$), but that this

reduction did not significantly impact the distribution of soil carbon within the soil profile in both Merrimac and Enfield soils.

For riparian ecological sites, I aimed to develop concepts to differentiate poorly drained (Walpole) and very poorly drained (Scarboro) soils. Both the Walpole and Scarboro riparian sites had stands of *Acer rubrum*, but there were observable differences in the understory species composition that support separate ecological sites for these soil systems. *Carex stricta* and *Symplocarpus foetidus* were the two species that seemed to indicate the very poorly drained conditions of the Scarboro soils. Within the upper 50 cm, Scarboro soils averaged 210 Mg C ha^{-1}, which was greater than the 116 Mg C ha^{-1} recorded for Walpole ($p=0.17$). The higher water table found at the Scarboro sites is the likely cause of increased organic matter accumulation and thus the higher SOC pool that was observed in comparison to the other soils used in this study. In a plot enrichment study, I compared two levels of nitrogen additions (7.5 and 15 g N m^{-2} yr^{-1}) with a control to determine whether nitrogen enrichment alters dynamic soil properties in riparian sites with Scarboro soils. Root biomass, measured in the upper 20 cm, was 4.6 times greater in the high treatment when compared to the control ($p=0.006$). The low treatment showed a similar trend with 1.6 times more root biomass than the control ($p=0.135$). Thus, N may be a limiting nutrient for plant growth in these riparian soils. Although there were significant root biomass differences, above ground biomass values were similar across treatments.

In salt marshes, Ipswich and Matunuck soils were investigated to determine how these soils respond to ditching and whether or not they are different ecological sites. The main difference between Ipswich (Histosols) and Matunuck (Entisols) soils

is the thickness of organic materials. Based on the kind of vegetation present and the response of the vegetation to salt marsh ditching, these soils are the same ecological site. On both soils, *Spartina patens* and tall *Spartina alterniflora* were most common at or near the edge of the ditch and short *S. alterniflora* and salt marsh pannes occupied zones inward from the ditch. The productivity and distribution of individual salt marsh species is based on several factors including soil salinity, which is often a function of the distance of the pedon to the marsh-water interface. Four passive open-topped warming chambers (OTCs) were installed on an Ipswich soil to determine how increased temperature will effect soil carbon dynamics. I concluded that OTCs can successfully increase air temperatures, but modifications to the design used in this study may be necessary to achieve projected (1.5-4 °C) temperature increases. Post-season biomass was 32% greater in the OTC plots in 2012 ($p=0.06$) and 91% more in 2013 ($p=0.01$), suggesting higher temperatures could increase productivity in salt marshes. However, potential increases in carbon additions to the soil may be offset by increased decomposition.

I used macroinvertebrate distributions to compare Massapog and Pishagqua soils to illustrate that subaqueous soils can be viewed through an ecological site framework. Massapog soils are part of the flood-tidal delta, a high energy environment near the estuary's inlet. These soils are sandier and have less SOM compared to the Pishagqua soils, which form on the bay floor, an area protected from high energy deposition. Because of their different geomorphic settings, 94% of the invertebrate community sampled from the Massapog soils were filter feeders, while in the Pishagqua soils the benthic community mostly consisted of deposit feeders (78%). Invertebrate density

was reduced in dredged sites by 97 and 71% for the Massapog and Pishagqua soils, respectively. In the Massapog soils, dredging increased water depths promoting eelgrass colonization. This change induced a shift from dominantly filter feeding organisms such as *Mya arenaria* and *Clymenella torquata* to deposit feeders including *Nephlys picta* and species in the Ampeliscidae family. The invertebrate community in the Pishagqua soils was similar between the dredged and control site, indicating that these soils likely respond differently to dredging. I found that water depth strongly influences the presence of eelgrass, likely because depth influences light availability. I believe that in most cases dredging lagoon bottom soils will inhibit their ability to support eelgrass because depth will be too great. In contrast, dredging in the flood-tidal delta could inhibit or induce eelgrass presence. For both Massapog and Pishagqua dredging increased depth which resulted in finer textures and greater SOC accumulation.

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PREFACE

This thesis was prepared in standard format as specified by the University of Rhode Island Graduate School guidelines. There are two chapters: Assessing Dynamic Soil Properties in Southern New England Forests Using an Ecological Site Framework (Chapter 1) and Soil-Vegetation Dynamics Relative to Human Disturbance in Estuarine Intertidal and Subtidal Wetlands (Chapter 2).

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ABSTRACT

In this study, ecological site concepts were developed for upland and forested riparian benchmark soils. In each system, I quantified the resistance or resilience of dynamic soil properties, mostly related to soil carbon, following management or disturbance. In uplands, Merrimac (sandy) and Enfield (silty) soil components with either deciduous or coniferous cover were compared to determine whether or not these soils are different ecological sites. Within the upper 50 cm, Merrimac soils averaged 61% sand, which was significantly greater than the 26% recorded for Enfield ($p<0.01$). Although this supports that these soils differ in drainage, these soils had similar organic carbon pools (109 and 101 Mg C ha^{-1} for the Merrimac and Enfield, respectively; $p=0.66$). Similarity in vegetation composition and tree productivity suggest that these soils have similar ecological potential. Selective harvest of 50% of overstory trees decreased carbon additions from litter by 28% ($p=0.036$), but this reduction did not significantly impact the distribution of soil carbon within the soil profile suggesting these soils were resilient to change. For riparian ecological sites, I aimed to develop concepts to differentiate poorly drained (Walpole) and very poorly drained (Scarboro) soils. Both the Walpole and Scarboro riparian sites had stands of *Acer rubrum*, but there were observable differences in the understory species composition that support separate ecological sites for these soil systems. *Carex stricta* and *Symplocarpus foetidus* were the two species that seemed to indicate the very

poorly drained conditions of the Scarboro soils. Within the upper 50 cm, SOC pools for Scarboro sites averaged 210 Mg C ha^{-1}, which was greater than the 116 Mg C ha^{-1} recorded for Walpole ($p=0.17$). The higher water table found at the Scarboro sites is the likely cause of increased organic matter accumulation and thus the higher SOC pool that was observed in comparison to the other soils used in this study. In a plot enrichment study, I compared two levels of nitrogen additions (7.5 and 15 g N m^{-2} yr^{-1}) to determine whether nitrogen enrichment alters dynamic soil properties in riparian soils. Root biomass, measured in the upper 20 cm, was 4.6 times greater in the high treatment when compared to the control ($p=0.006$). The low treatment showed a similar trend with 1.6 times more root biomass than the control ($p=0.135$).This finding supports that N may be a limiting nutrient for plant growth in forested riparian systems. Thus, N may be a limiting nutrient for plant growth in these riparian soils. Although there significant root biomass differences, above ground biomass values were similar across treatments.

INTRODUCTION

Soil-based interpretations are an effective decision-making tool for land use and management. Commonly used soil interpretations include suitability of the land for building roads, supporting houses with basements, and siting for septic tank absorption fields (Soil Survey Staff, 2008). Over the past decade, the Natural Resource Conservation Service (NRCS) and soil survey activities are transitioning toward a more ecological approach to soils and soil interpretations (Herrick et al., 2006). Herrick et al. (2006) noted that this change in approach is the result of an increase in our understanding of how ecosystems function. In addition, the demand for consistent management and monitoring across regions has increased in order to achieve broad scale management goals (Herrick et al., 2006). Ecological site descriptions (ESDs) are a tool that has been developed for monitoring and documenting the condition of ecosystems across regions with similar landscapes. An ecological site is defined as a distinctive kind of land based on recurring soil, landform, geological, and climate characteristics that differs from other kinds of land in its ability to produce distinctive kinds and amounts of vegetation and in its ability to respond similarly to management actions and natural disturbances (NRCS, 2013). ESDs provide a consistent framework for describing soil, vegetation, and abiotic features; delineating landscape scale units that share similar responses to management activities or disturbance processes; and estimating ecosystem services that can be expected from particular soil/vegetation combinations (Townsend, 2010).

Unlike typical vegetation surveys, ESDs provide land managers with an understanding of the potential vegetation that may exist under certain management

conditions rather just a snapshot of the existing vegetation. To document several potential vegetation communities that may exist on a given site, each ESD has an associated state and transition model (S&TM) which describes a reference state of vegetation and a series of alternative states that have transitioned from the reference community through management or disturbance (Briske et al., 2005). In the past, the reference community has been defined as the plant community that existed at the time of European immigration and settlement (NRCS, 1998).

In New England, reforestation of previously cleared land, five centuries of extensive land use, and changes in aspects of environmental conditions have shifted regional forest communities from long lived, shade tolerant species to secondary, shade intolerant species (Foster et al., 1998). Changes in the ecology of the New England forests, including increased atmospheric acid deposition, nitrogen loading, and disease have favored the colonization of species that were not dominant during pre-colonial times (Bromley, 1935; Johnson and Siccama, 1983). Specifically, species such as beech, hemlock, elm, hickory, and chestnut have decreased since pre-European settlement, while highly productive and widely dispersed species such as oaks, maples, and pines have increased (Foster et al., 1998; Hall et al., 2002). Therefore, finding sites that represent the state that existed before colonial times is essentially impossible. As such, mature plant communities that represent current climatic and environmental conditions, and are common throughout the landscape, are the key to understanding dynamic soil properties under recent environmental conditions (Duniway, 2010).

Forest land cover and productivity in the eastern US has increased dramatically over the last century due to agricultural abandonment, shifts from public to private land ownership, and the reduced demand for fuel wood and lumber (Clawson, 1979). Over 59% of southern New England, which includes Connecticut, Rhode Island, and Massachusetts, is currently forested (Butler et al., 2007). Although New England has experienced multiple land-use shifts over the last 400 years, most of the work focused on ESDs has taken place in rangeland in the western states of the US. Townsend (2010) reported that less than 10% of the 7000 ESDs that had been recorded were made for forested ecosystems, and no ESDs had been made in southern New England. The current goal for NRCS and partnering agencies is to have provisional ecological site descriptions across the country within the next five years (Brown, 2015; personal communication). In order to meet this goal, concepts to distinguish forested ecological sites in New England must be developed.

Soil properties used to differentiate ecological sites are typically inherent such as soil texture or parent materials (Duniway et al., 2010). In the US, soil scientists have used Soil Taxonomy (Soil Survey Staff, 2014) to classify soils with similar inherent properties and delineate soil map units. Since the scale of individual soil bodies is often finer than the scale of mapping, soil map units often contain multiple different soils identified as components (Duniway et al., 2010). Soil map unit components provide the best opportunity to identify soils with similar ecological potential which can be used to develop ecological site concepts (Duniway et al., 2010).

Unlike the inherent properties used for mapping soils, dynamic properties are those with potential to change with management or disturbance. In New England, soil

carbon and nitrogen are dynamic in respect to changes in land use such as agricultural abandonment (Compton and Boone, 2000; Stolt et al., 2010). Understanding the resistance and resilience of these properties to change is important for making land use decisions, especially now that we recognize their role in ecosystem services.

The primary objective of this study was to initiate provisional ecological site concepts for forested riparian and upland glaciofluvial soils in southern New England by comparing sites that share similar geomorphic settings, but differing soil types. Specifically in uplands, I wanted to test if soils with contrasting particle size classes differ ecologically. For riparian ecological sites, I aimed to develop concepts to differentiate poorly drained (mineral) and very poorly drained (organic) soils. To begin to develop an understanding of the underlying ecological processes that lead to changes in soil properties with disturbance, I quantified the effects of two drivers of change to forest soil dynamic properties: selective harvesting in upland soils and increased nitrogen loading in riparian soils. These disturbances ultimately represent a transition from a reference state in the state and transition model (S&TM).

Forested Uplands and Selective Harvesting

Numerous studies have focused on environmental and historical influences on forest community composition and dynamics on a regional scale (Foster et al., 1998, Fuller et al., 1998; Hall et al., 2002). Most of these studies document long-term and widespread trends in forest composition. In contrast, other studies have focused on the response of specific soil or vegetation properties to management. For example, Compton and Boone (2000) studied changes in New England forest soils resulting from historic logging and cultivation, but neglected the response of vegetation.

Developing an understanding of regional forest dynamics and specific biotic or abiotic properties does not provide land managers with an effective tool to predict the effect of disturbance at a local scale. Instead, an ecological approach that considers changes in both vegetation and soils should be used to develop an understanding of how use and management affect the ecosystem functions and values.

In some forests, clear-cutting is an inappropriate means of harvesting timber because it can lead to management issues concerning wildlife habitat, soil stability, and water quality (Keenan and Kimmins, 1993). Therefore in many situations, alternative practices including patch cutting and selective harvesting have been implemented to reduce impacts of logging on ecosystem services. Selective cutting is a silvicultural practice in which only desired trees are removed resulting in an uneven forest stand. A study by Brooks and Kyker-Snowman (2008) showed that partial harvesting of the forest canopy has minimal effects on forest soil temperature and humidity, possibly due to the rapid growth of understory vegetation following timber removal. The effects of selective cutting on other soil dynamics, such as carbon distribution in New England forests, is currently in question. A timber product output survey conducted in 2004-2005 claimed that one third of the timber harvested in southern New England was eastern white pine (*Pinus strobus*); of which 90% was harvested for commercial timber (Butler et al., 2007). In this study, I used a paired site approach to document changes in soil and vegetation dynamics between selectively harvested and uncut stands of *P. strobus*. Specifically, I wanted to determine how carbon additions from litter, deadfall, and emergent vegetation change with harvesting

and if these changes induce a response in the amount and distribution of soil organic carbon.

Forested Riparian Zones

Forested riparian zones occupy the interface between upland and aquatic systems and provide ecosystem functions such as flood mitigation, water quality improvement, and wildlife habitat (Mitsch and Gosselink, 2000). For example, riparian soils act as a sink for nitrogen additions from ground water, precipitation, and surface runoff (Lowrance et al., 1984; Galloway et al., 2003) through the process of denitrification. Addy et al. (1999) found that forested riparian soils exhibit higher ground water nitrate removal rates than herbaceous riparian soils suggesting land use and cover has an effect on riparian zone soil functions.

Additional N that is not removed via denitrification may influence vegetation productivity and microbial activity which affects other soil processes such as soil respiration. Total soil respiration is the result of the production of CO_2 from microbial decomposition, diffusion through culms, and root and rhizome respiration (Howes et al., 1985; Wigand et al., 2009). Although respiration from fine roots is a major contributor to soil respiration, decomposition is responsible for increased respiration with nitrogen loading. With increased nitrogen availability root production increases but high root turnover rates may result in less belowground biomass (Valiela et al., 1976; Nadelhoffer, 2000). If this is the case, carbon dynamics in the soil system may be altered.

There has been contrasting reports as to the effect of increased nitrogen loading on short term soil respiration efflux in upland forest soils; with some studies

suggesting no effect (Lee et al., 2003), other studies report an increase in respiration (Pregitzer et al., 2000), while still other studies a decrease (Bowden et al., 2004; Mo et al., 2008; Janssens et al., 2010). In tidal wetlands, however, respiration has been shown to increase with nitrogen loading (Valiela et al., 1976; Wigand et al., 2009). These contrasting findings suggest that the response of soil respiration to increased nitrogen varies between ecosystems and associated soil types. In this study, I used a plot enrichment experiment to clarify the fate of soil respiration and related dynamic soil properties in forested riparian zones resulting from nitrogen additions.

METHODOLOGY

Site Selection

The soils of southern New England are the result of the advance and retreat of last glaciation which occurred between 10,000 and 25,000 years ago (Boothroyd and Sirkin, 2002). Glaciofluvial deposits are stratified soil materials that were deposited via meltwater from receding glaciers (Gustavson and Boothroyd, 1987). These deposits are often capped with silty loess that was deposited over the landscape following glacial retreat (Boothroyd and Sirkin, 2002). The glaciofluvial soil types chosen for this study either occur over a large extent of MLRA 144A, hold a key position in the soil classification system, have previously been well characterized, have economic importance, or provide valued ecosystem services (Soil Survey Staff, 2008). These soil types are referred to as benchmark soils and typically used as proxies for similar soil types (Soil Survey Staff, 2008).

In this study, ecological site development and drivers of dynamic soil properties were investigated in upland and riparian settings. For the upland ecosystems, benchmark glaciofluvial soils representing the Merrimac series (Sandy, mixed, mesic Typic Dystrudepts) were compared with loess capped glaciofluvial soils of the Enfield series (Coarse-silty over sandy or sandy-skeletal, mixed, active, mesic Typic Dystrudepts). For forested riparian systems, consociations containing poorly drained soils of the Walpole series (sandy, mixed, mesic Aeric Endoaquepts) were compared with very poorly drained soils of the Scarboro series (sandy, mixed, mesic Histic Humaquepts). A GIS spatial inventory was conducted to identify a range of forested sites mapped as consociations of the desired series as the dominant soil map

unit component. Historic and recent aerial photography were used to confirm all sites are over 50 years old, and that none have been disturbed during the timeframe. Both upland and riparian sites were field checked in an initial reconnaissance survey and sites representing the combination of soils, setting, and vegetation communities identified in the spatial data were chosen for study.

To initiate ecological site development of forests, three deciduous and three coniferous upland sites of both the Merrimac (sandy) and Enfield (silty) were chosen and three sites of each riparian soil (Walpole, mineral epipedon vs. Scarboro, histic epipedon) were chosen for study (Table 1.1). All of the riparian forests had a canopy primarily composed of red maple (*Acer rubrum*). At each site a 100 m^2 fixed area plot was delineated in relatively homogeneous vegetation, landform, and topographic positions (NRCS, 2013). The following vegetation data were gathered within each plot; stand age, stand growth rate, total stratum cover, and species cover (NRCS, 2013). Stratum cover was estimated visually and recorded as a percentage. Cover classes were used to document individual species. The wetland indictor status of each species was recorded from The National Wetland Plant List (Lichvar, 2012). A minimum of three tree cores from randomly selected dominant tree species were collected using an increment borer. Stand age and growth rates were determined by counting annual rings (NRCS, 2004). Mean annual precipitation and air temperature were extracted from PRISM 1981-2010 normal annual precipitation and temperature datasets using GIS (PRISM, 2015). Elevation was derived from Rhode Island LIDAR (RIGIS, 2012). Detailed morphological descriptions were conducted via shallow pit to classify each pedon. For each soil, horizon thickness; soil structure size, shape, and

grade; root abundance and size; moist consistence; and hue, value and chroma were recorded in the field following the NRCS Field Book for Describing and Sampling Soils (Schoeneberger et al., 2012). Sampling was conducted by genetic horizon to a depth of 50 cm.

An ecological site inventory was conducted at three selectively harvested coniferous upland sites (~50% mature trees removed within the last 15 years; Table 1.1). Each selectively harvested site was paired with a control to quantify the effects of harvesting on soil-vegetation dynamics. At each paired site, four sampling stations were set up in relatively homogeneous areas of vegetation, landform, and topographic position to document carbon additions from litter, woody debris, and emergent vegetation. A litter tray (27 x 53 cm) equipped with nylon screening to capture fine leaf litter, and affixed to the ground with 15 cm landscaping staples was installed at each sampling station (Richardson, 2006). Litter trays were sampled monthly from September through November, and at the end of August during a period when minimal litter deposition occurs (Richardson, 2006). Along with each litter tray, a 1 m^2 plot was delineated at each station to measure emergent vegetation and deadfall (any woody debris greater than 1 cm; Richardson, 2006). Prior to field collection, plots were cleared of existing vegetation and deadfall. After one year, all deadfall and emergent vegetation within the plots was collected for laboratory analysis.

To investigate the fate of soil dynamics in riparian zones, three Scarboro sites (HLS, BZS, VRS) were chosen for the nitrogen enrichment experiment. At each of these sites, three clusters, each containing three 1 m^2 plots were marked to receive different N-addition treatments (control, low, and high). To simulate nitrogen

enrichment in riparian soils, urea dissolved in 10 L of water from the adjacent stream was applied to each treatment plot. Water with no added nitrogen was added to the control plots. The low treatment consisted of two additions of urea totaling 7.5 g N m^{-2} yr^{-1}. This addition is equivalent to the upper range of atmospheric N-deposition concentrations in the northern hemisphere (Galloway, 2003) and annual N loads in the region (Lowrance et al., 1995; Ettema et al., 1999). The high treatment was applied in two pulses and equivalent to 15 g N m^{-2} yr^{-1}. Nitrogen was not applied to the control plots. Prior to the riparian zone nutrient addition experiment, simulated soil peds, also known as in-growth cores, were buried within each plot to measure carbon additions from fine root production (Stolt et al., 1998; Ricker et al., 2014). In-growth cores were constructed in nylon bags with 15-cm length and 4-cm diameter and buried to a depth of 5-20 cm (Ricker et al., 2014). The bags were filled with mineral soil material collected from the upper horizon of a riparian soil similar to the soils present at each site. In-growth cores were retrieved after two growing seasons and sieved to determine root content. In-situ CO_2 efflux measurements were made monthly throughout two growing seasons using a Li-Cor 6262 infrared gas analyzer (Li-Cor, Lincoln, Nebraska). One 25 cm diameter PVC collar was installed in the center of each plot two weeks prior to the initial nutrient addition to a depth of 2.5 cm, which was used to create a seal between the Li-Cor analyzer and the soil. The PVC collars were left in place throughout the duration of this experiment (Davis et al., 2010). At the end of each growing season, herbaceous understory vegetation within each plot was clipped at the soil surface and returned to the lab to determine aboveground biomass production.

Laboratory Analysis

Soil organic matter, particle size, bulk density, and carbon and nitrogen content were measured for each soil sample. Soil bulk density was measured by dividing the soil dry weight (105 ºC) by a known volume taken from each soil horizon (Blake and Hartge, 1986). Soil organic matter content was measured via the loss on ignition method (Nelson and Sommers, 1996). Dried samples were ashed at 550 °C for 5 hours in a muffle furnace and weighed on a 4-place balance. Total soil organic carbon and nitrogen were measured using an ECS 4010 CHNSO Analyzer (Costech Analytical Technologies, Valencia, CA). Sand content and sand fractions were determined using a nest of sieves and a combination of wet and dry sieving techniques. The pipet method was used to measure clay content (Soil Survey Laboratory Staff, 2004). Silt was calculated by subtracting the percent sand and clay from the total sample weight. The pH of all soil samples was measured using a bench top pH meter in a 1:1 soil-water mixture (Soil Survey Laboratory Staff, 2004).

Diameter at breast height (1.4 m) age was determined by counting annual rings from tree cores under a dissecting scope in the lab. For diffuse porous species such as *Acer rubrum*, annual rings were distinguished using a phloroglucinol dye solution (NRCS, 2004; Richardson and Stolt, 2013). Age correction factors were used to add the number of years for the tree to reach breast height (NRCS, 2004) and used to calculate the total age (Carmean et al., 1989). All tree data for *Quercus spp.* were grouped for analysis. For this study, stand age was reported as the average age between dominant tree species. Roots from the in-growth cores were separated using tweezers, shaken for 12 hours in 0.5 g L^{-1} sodium hexametaphosphate to remove soil

material, and rinsed (Ricker et al., 2014). All litter, deadfall, and plant biomass samples were oven dried at 60 °C, and weighed. It was assumed that half of the oven dry weight of all plant samples was carbon (Nelson and Sommers, 1996).

Statistical Analysis

Soil properties were weighted by horizon thickness and averaged for the upper 50 cm. Total soil carbon in the upper 50 cm was calculated and compared between soil types. The number and proportion of species within each wetland indicator category (Lichvar, 2012) and total species richness were calculated by soil type for comparison. For the upland sites, two-way Analysis of Variance (ANOVA) tests were used to determine the effects of soil and cover type on vegetation, site attributes, and soil properties. When a significant difference was detected, Tukey's test was used to determine which means differed. Data were compared between Scarboro and Walpole riparian sites as well as upland harvested and control sites using paired t-tests. For the riparian enrichment experiment, ANOVA was used to test for differences between the two fertilizer treatments and the control. When differences were detected, a pairwise multiple comparison test (Holm-Sidak) was used to determine which treatments differed from the control.

RESULTS AND DISCUSSION

Site and Soil Attributes

Upland Soils

Precipitation, temperature, and elevation were similar between all upland and riparian sites ($p > 0.05$). Of the twelve upland sites chosen for vegetation comparison (Figure 1.1), six were representative of the Merrimac series (Table 1.1). Classification of the silty soils revealed five sites representative of the Enfield series and one site (YWC) with a thicker loess cap (127 cm), which correlated to the Bridgehampton series (Table 1.1). Loess thickness of the Enfield sites ranged from 73-90 cm (Appendix I). Although the YWC pedon is more similar to Bridgehampton, this site was grouped with the Enfield soils for statistical analysis.

Soil property weighted average means of the upper 50 cm of the soil showed significant differences between the Merrimac and Enfield soils (Table 1.2). Merrimac soils form in outwash deposits and thus had more sand, and less silt and clay than the Enfield soils which form in silty loess materials (Table 1.2). Further examination of the sand fractions revealed more fine to very coarse sized sands (0.1 - 2 mm) in Merrimac, but no difference in very fine sand (Table 1.2). The sandier Merrimac soils have a lower available water holding capacity than the silty loess-capped Enfield soils; which is important in plant growth and may support differentiating these soils as separate ecological sites. Average pH was higher in the Enfield than Merrimac soils. The higher pH is likely because of the higher buffering capacity associated with the higher clay content in the Enfield soils. The rest of the soil properties I measured, moisture content, O horizon thickness, bulk density, SOM, SOC, and nitrogen

contents, showed no significant differences between the soils (Table 1.2). Cover type (coniferous vs. deciduous) and the interaction between soil and cover had no effect on any of soil properties measured.

Riparian Soils

The six riparian sites used in this study (Figure 1.2) were mapped as either Walpole or Scarboro soils (Table 1.1). KPW was mapped as Walpole but did not have the dark colors required for an umbric epipedon and therefore failed to meet the great group criteria for the series. The Scarboro taxadjunct (VRS) failed to meet the subgroup classification because it lacked the thickness requirement for a histic epipedon. Although these two soils did not match the series classification that they were mapped, their similar morphology and drainage class made it practical to include them in this analysis. Because the Scarboro soils had histic epipedons or had thick O horizons, particle size distribution data were not be used to differentiate these soils. No significant differences were observed in bulk density or pH between riparian soil types (Table 1.3). The main difference between Scarboro and Walpole soils was the organic horizon thickness, which averaged 21 cm thick for Scarboro soils and 3 cm for Walpole. The thicker O horizons of the Scarboro soils likely explains the higher levels of C and N (7 and 0.4% more, respectively) than Walpole soils. Extended periods of saturation and anaerobic conditions closer to the surface in the Scarboro soils is likely the cause of higher organic matter accumulation. Under these conditions low oxygen levels constrain microbial decomposition and organic matter accumulation increases (Mausbach and Richardson, 1994).

Soil Carbon Pools

Upland sites (M = 104, SD = 27) had significantly less carbon in the upper 50 cm than riparian sites (M = 163, SD = 80; p = 0.03; Figure 1.3A). This finding is consistent with a study by Davis et al. (2010) who found that carbon pools increase as soils move toward a wetter class (i.e. moderately well drained to poorly drained). The very poorly drained Scarboro sites had a greater SOC pool than poorly drained Walpole, but the difference was only significant when the Scarboro taxadjunct (VRS) was excluded from the data (Figure 1.3B). Carbon pools were similar between Merrimac and Enfield soils (p = 0.927; Figure 1.3A). Davis et al. (2010) found that excessively drained outwash soils of the Windsor series had higher SOC pools than Enfield (well drained). Although Merrimac (somewhat excessively drained) is better drained than Enfield, the difference in hydrology does not appear to affect carbon pools within the upper 50 cm. McLauchlan (2005) found that soil texture is not a significant factor in SOC accumulation across several sites with grassland vegetation. No significant differences in SOC were detected between upland sites with deciduous vegetation and those dominated by conifers.

Ecological Site Characterization

Upland Vegetation and ESDs

Species richness was similar between Merrimac and Enfield soils (p = 0.72; Appendix II) and between sites with coniferous and deciduous cover (p = 0.81). Upland sites of both soil types contained mostly facultative and facultative upland species (Figure 1.4). A total of 9 tree species were observed in the upland canopy stratum, which for this study, was defined as woody vegetation greater than 10 m. The

deciduous sites were classified as oak woodlands in the Rhode Island Ecological Communities Classification (RIGIS, 2014). The majority of canopy species were oaks and pines, with the exception of *Acer rubrum* (red maple), which was a major canopy species at several sites on both upland soil types. *A. rubrum* is known to be a generalist species that grows on a variety of soil types that is also tolerant of drought and shade (Fergus and Hansen, 2005). Since it can tolerate a vast majority of environmental conditions, the presence of *A. rubrum* alone, does not provide any insight for differentiating silty versus sandy upland glaciofluvial sites.

The coniferous sites used in this study were identified as plantation and ruderal forest in the Rhode Island Ecological Communities Classification (RIGIS, 2014). Coniferous Merrimac sites were dominated by *P. strobus*, but also contained several hardwood species analogous to the deciduous sites. *P. strobus* has been known to invade disturbed sites, such as abandoned fields or pasture, and mature to old growth forest (Hibbs, 1982; Abrams, 2001). *Pinus rigida* (pitch pine) was a major constituent of the canopy at one Merrimac site (BZM), likely the result of the large fire which took place in much of western Rhode Island in the early 1930s (Kivela, 2009; Dupree, 2012; personal communication). *P. rigida* has thick bark, serotinous cones, and is capable of stump-sprouting making it highly fire-adapted (Fergus and Hanson, 2005). *P. strobus* and *P. rigida* were absent from the deciduous Merrimac soils sampled in this study. Two of the deciduous Merrimac sites were dominated by *Quercus velutina*, where at the third, *Quercus coccinea* accounted for the most cover. Both of these species fall within the red oak category of oak species in New England (Fergus and Hanson, 2005). Red oaks are defined by having pointed tipped leaves and can thrive

under a variety of soil types (Fergus and Hansen, 2005). These species are intolerant of shade and also hybridize regularly making field identification difficult (Fergus and Hansen, 2005). Therefore using the presence of one red oak species over another to support ecological site concepts is limiting. The subcanopy tree and shrub strata for the Merrimac sites was similar between cover types and was mainly composed of young hardwood trees and shrub species in the heath family Ericaceae. The species Ericaceae are known for tolerating highly acidic and nutrient poor soils, such as those observed in this study (FEIS, 2015). The herbaceous strata accounted for most of the species richness in Merrimac sites. In this strata, the most reoccurring species were *Vaccinium angustifolium*, *Rubus hispidus, Mainanthemum canadensis*, *Acer rubrum*, and *Carex pennsylvanica*, all of which occur over a broad span of soil and site conditions in New England (FEIS, 2015).

Similar to the Merrimac sites, deciduous Enfield sites were mainly composed of oaks whereas coniferous canopies were primarily composed of *Pinus strobus*. *Pinus rigida* was also encountered at two of the Enfield sites. The composition of oaks was slightly different between deciduous Merrimac and Enfield sites. A greater portion of the oaks in the canopy of Enfield sites were *Quercus alba*, commonly known as white oak. White oak is the most shade tolerant of New England oak species and are thought to be a climax species in mixed forests (Fergus and Hansen, 2005; FEIS, 2015). More white oak in the Enfield canopy may indicate differences in site conditions which favor white oak, or may be an indication that these sites represent a later stage of succession. Subcanopy and shrub communities of the Enfield sites were similar to Merrimac being mostly composed of tree saplings and Ericaceae shrubs. Species that

occurred over the majority of Enfield sites were: *Acer rubrum*, *Lycopodium obscurum*, and *Trientalis borealis*. Although these plants occurred at a higher frequency in Enfield soils, their occurrence in the Merrimac soils indicates they cannot be used as species to differentiate these soils as separate ecological sites. Overall, vegetation composition is too similar between Enfield and Merrimac to distinguish them as separate ecological sites.

Riparian Vegetation and ESDs

Average total species richness did not differ between upland and riparian soils ($p = 0.32$). Based on the National Wetland Indicator List, the composition of riparian flora contained more obligate and facultative wetland species than upland sites and less facultative, facultative upland, and upland species ($p = <0.01$; Figure 1.4). Since all six sites met the criteria for a hydric soil, it is not surprising that these sites contain more hydrophytes than the well and somewhat excessively drained upland soils. No meaningful relationship between the two riparian soil types and the amount, or proportion of species within any of the wetland indicator classes was determined (Figure 1.5).

No significant difference was observed when the total percent cover of vegetation within each strata was compared (canopy, shrub, herbaceous, etc.). The composition of canopy tree species observed on both riparian soils was almost exclusively *Acer rubrum* with the exception of a facultative upland species *Betula lenta*, or sweet birch, which was found at two of the Scarboro sites (HLS and VRS). Shrubs were abundant on both riparian soil types. Shrubs on Walpole soils were mainly *Clethra alnifolia, Lindera benzoin*, and *Vaccinium corymbosum*. Shrub

composition was similar for the Scarboro soils, but included *Rhododendron viscosum*. This species, commonly known as swamp azalea, is considered an obligate wetland species in the Atlantic region of the U.S. Since *B. lenta* and *R. viscosum* were exclusive to Scarboro, these species may be useful indicators for differentiating ecological sites, but since *B. lenta* is facultative it is more likely that its occurrence was by chance. Species in the herbaceous stratum mostly consisted of grasses and forbs typical of southern New England wetlands, such as *Carex intumescens*, *Osmundastrum cinnamomeum*, and *Parathelypteris noveboracensis* which were found at all six sites. *Carex stricta* and *Symplocarpus foetidus* were two species that were absent from Walpole, but occupied all three Scarboro sites. *Carex stricta*, or tussock sedge, is a species that prefers soils were the water table is at or just below the soil surface (FEIS, 2014). It may be that *C. stricta* and *S. foetidus* may be absent from Walpole soils since they are better drained.

Tree Growth Analysis

Average stand age for upland forests ranged between 58-96 years old and did not differ between Enfield and Merrimac soils ($p = 0.57$; Appendix III). Merrimac *P. strobus* did average 12 ft (3.7 m) taller ($M = 74.8$, $SD = 7.3$) than what was recorded for Enfield ($M = 62.9$, $SD = 1.5$; $p = 0.05$), but growth rates were similar between soil types ($p \geq 0.05$). The native range of the tree species that were identified in this study occur across a gradient of annual precipitation throughout North America spanning from 50 to 200 cm (Burns and Honkala, 1990). High levels of precipitation in forested ecosystems can allow a great range of soil textures to have the same ecological potential (Townsend, 2010). The upland sites in this study receive a high amount of

precipitation (M=128 cm, SD =3.7) relative to the native range of the species observed. The high water availability is likely the reason for the similarity in tree growth between Enfield and Merrimac soils, and thus, does not support separate ecological sites for these soils in southern New England. Cores collected from riparian sites indicate that *Acer rubrum* stands were similar in age, height, growth rate, and site index between Scarboro and Walpole soils ($p \geq 0.05$).

Upland Selective Harvesting

Selectively harvested sites (YWH, FPH, PTH) were each paired with a control site for analysis (YWC, FPC, PTC). The locations of these sites are shown in Figure 1.1. Soils at one harvested site (YWH) were correlated to the Enfield series and were compared with YWC Enfield site used as a control (Table 1.1). Canopy cover at YWH was 50% less than the control. Subcanopy tree, shrub, and herbaceous cover were also less at the control site, possibly because of the high amount of deadfall in the area. At YWC, the canopy species that were left following harvesting practices were a mixture of *P. strobus* and *Q. veluntina*. *P. strobus* was also recorded in the lower strata indicating that the species may regenerate following succession. Most of the species observed in the shrub and herbaceous strata such as *Gaylussacia baccata*, *Kalmia latifolia*, and *Vaccinium angustifolium* were found at both YWH and YWC.

Soils at the other two harvested sites (FPH, PTH) correlated to the Merrimac series and were compared to FPC and PTC, respectively. The canopy stratum at FPH, which was 55% more than the control, consisted of *P. strobus* and a mixture of both *Quercus coccinea* and *Quercus alba*. These species were also observed at the control, but *P. strobus* accounted for more of the total canopy. Low herbaceous cover (<0.5m)

was 45% higher at the FPH site than the paired control, likely due to an increase in canopy gaps. Species richness was higher at the harvested site. Although FPH had higher herbaceous cover when compared to the control, the species composition of was similar between these sites with *Gaylussacia baccata* and *Vaccinium angustifolium* being the most common species.

Similar to YWH and FPH, PTH canopy species were a mixture of *P. strobus* and hardwood species such as *Q. velunita*. Although canopy cover was only 20% at the PTH, which was 40% less than the control, shrub and lower herbaceous cover were similar to the control. Tall herbaceous cover was 40% higher at the harvested site (PTH) due to the high abundance of *Dennastaedtia punctilobula*, commonly known as hay-scented fern. A study on the distribution and dynamics of this species showed that this fern prefers canopy gaps, such as those created by logging, and once established can persist for long periods of time (Hill and Silander, 2000). Species richness did not differ between PTH and PTC.

Overall, the response of the vegetation to selective logging seems site specific. The two Merrimac harvested sites both had higher herbaceous cover, but at FPH the higher cover was the result of several species colonizing canopy gaps, and at PTH it was exclusively *D. punctilobula*. Reader and Bricker (1992) found that selective harvesting had no short or long term effects on herbaceous species loss following selective cutting. Similarity in species richness between the selectively harvested sites and the controls ($p=0.286$) supports this finding. Based on the data collected from *P. strobus* tree cores, harvesting also has no effect on tree productivity. Although

harvesting removes competition, more time may be required to observe a response in tree production.

Significantly less litter deposition and more emergent vegetation were observed at all three harvested sites when compared to their paired controls (Table 1.4). On average, control sites received 1.33 Mg ha^{-1} yr^{-1} more litter compared to harvested sites (p=0.036). When a linear regression was fit to the data a significant relationship was detected between canopy cover and annual litter deposition [$F(1,4)=18.733$, $p=0.012$, $R^2=0.824$]. Emergent vegetation did not follow this trend [$F(1,4)=1.057$, $p=0.362$, $R^2=0.209$]. Trends in amount of deadfall received during the study timeframe differed between paired sites. Less deadfall was observed in the plots at PTH and FPH than their controls, but deadfall at YWH was almost twice the amount measured at YWC. The high amount of deadfall at YWH was due to a small tree that fell within one of the plots which greatly influenced the data. When this data point was removed from the dataset, it was determined that deadfall was slightly higher at control sites but statistically similar between treatments (p=0.175). Although I concluded that selective harvesting decreases litter deposition and increases emergent vegetation production, harvested sites did not differ in organic horizon thickness, SOC within 50 cm, nitrogen, or pH. Therefore, it can be concluded that harvesting reduces carbon additions, but the soil-carbon dynamics of these particular soils show resilience to this disturbance 15 years after selective harvest.

Riparian Nutrient Enrichment

In-growth cores removed after two years of N additions indicated higher fine root biomass in the high treatment plots (p=0.006), but no difference was detected

between the low treatment plots when compared to the control (p=0.135). Other studies have also recorded short term increases in fine root production following nitrogen additions in upland soils (Safford, 1974; Pregitzer et al., 1993; Hendricks et al., 2000). Although these results support the findings of these studies, Yuan and Chen (2012) determined that, in wetlands, N enrichment was not important in influencing root production. Yuan and Chen (2012) attributed the negative response of root production to N-additions to high nitrogen content in the wetland systems (greater than 1%). Total fine-root biomass generally decreases with increasing nitrogen availability (Nadelhoffer, 2000). If root biomass decreases with increased nitrogen, but production increases as the data from the riparian plot enrichment suggests, then root turnover must also increase (Nadelhoffer, 2000). Nadelhoffer (2000) found that higher turnover is due to higher N concentrations in fine roots (Hendricks et al., 2000), which increases root metabolism and thus N cycling rates.

Although it seemed likely that faster turnover of fine roots would increase soil respiration, no response in respiration was detected between the three treatments in 2012 (p=0.460) or 2013 (p=0.283; Table 1.5). Soil respiration was highest during the months of July through August, but was similar between treatments (Appendix 3). No significant difference was observed between the amount of emergent vegetation between the control plots and the two treatments (Table 1.5). In 2013, the VRS site had significantly less emergent vegetation than both BZS (p=0.004), and the HLS site (p=0.010). In 2014, the same difference was observed between sites (p=0.003). As noted earlier, the VRS pedon did not meet the classification requirements for the Scarboro soil series as it was mapped. This site also had significantly lower respiration

rates in 2012 when compared to HLS (p=0.013) and BZS (p=0.044). VRS also had the lowest root biomass, but the difference was not statistically significant from the other riparian sites (p=0.484). The different morphology found at VRS could be the cause of lower above and belowground biomass production, which may have reduced respiration from the soil.

SUMMARY AND CONCLUSIONS

Merrimac or Enfield soil components with either deciduous or coniferous cover were compared to determine whether or not these soils are different ecological sites. The presence of deciduous, coniferous, and mixed forests on both sandy and silty upland glaciofluvial soils indicates that the forest cover type cannot be explained by the soil type alone. The presence of deciduous and coniferous stands on both soil types is likely the result of different disturbance regimes. Since oaks are drought tolerant, adapted to fire, and can colonize sites with poor nutrient conditions, oak dominated stands represent a state in which one of these disturbances occurs in high frequency (Abrams, 1992). Where drought and fire are absent and nutrients are plentiful, a coniferous state will be more likely. It is also apparent that many of the coniferous stands were planted. Either way, I believe the coniferous and deciduous communities observed in this study represent two different states or community phases within one upland forest ecological site.

The sites used in this study showed that even though the Merrimac soils are sandier and better drained than Enfield, the similarity in vegetation composition and tree productivity indicate that these soils have similar ecological potential. The slight differences in species composition that were observed between these soils was due to

variability in species distribution or competition, not because the site conditions were limiting. The similarity in vegetation composition could be due to the high amount of precipitation in southern New England relative to the range of precipitation these species thrive under. Similarity in the tree production data also supported similar ecological potential between these soils. Typically, herbaceous and shrub production are also measured to differentiate ecological sites. Since these variables were not measured in this study, there is still a chance that they should be different ecological sites.

Following the selective harvest of glaciofluvial upland sites, soil dynamic properties related to carbon were determined to be resilient to change. I concluded that the 50% removal of overstory trees decreases carbon additions from litter, but that this reduction does not significantly impact the distribution of soil carbon within the soil profile over the 15 years since selective harvest. The vegetation response to selective logging seems to be site specific. Canopy openings can lead to species such as *Dennastaedtia punctilobula* to outcompete other understory species, but this occurrence is haphazard, and the colonization of openings depends on a variety of factors including what species already occupy the site. Since the sites chosen were logged within the last 15 years, it may be that not enough time has passed to affect the properties recorded in this study.

I also investigated differences in ecological sites and dynamic soil properties in wetland forests. Both the Walpole and Scarboro riparian sites had stands of *Acer rubrum*, but there were observable differences in the understory species composition that support separate ecological sites for these soil systems. *Carex stricta* and

Symplocarpus foetidus were the two species that seemed to indicate the very poorly drained conditions of the Scarboro soils. In contrast, tree production did not support different ecological sites, but as mentioned earlier, herbaceous and shrub production may help differentiating these sites. The higher water table found at the Scarboro sites is also the likely cause of increased organic matter accumulation and thus the higher SOC pool that was observed in comparison to the other soils used in this study. Better drainage in the Walpole soils increases aerobic decomposition which explains why these soils lack a thick organic surface horizon and have lower SOC pools.

In riparian zones, I tested whether nitrogen additions alter dynamic soil properties in Scarboro soils and found that N was a limiting nutrient for plant growth. Although the aboveground biomass measurements did not support this conclusion, the increase in root growth showed that N could increase plant production. No conclusions could be made on how nitrogen additions influence short term riparian soil respiration. Average nitrogen in the upper 50 cm was similar between the Walpole and Scarboro soil types. Since my findings suggest they are different ecological sites, it is possible that the response of soil-vegetation dynamics to nitrogen enrichment in Walpole could differ from Scarboro.

TABLES

Table 1.1: Summary of upland and riparian study sites. Mean annual precipitation (MAP) and mean annual air temperature were determined from the PRISM dataset (2015).

Site	Soil	Soil Component	Cover Type	Classification	MAP (cm)	MAT (°C)	Lat.	Long.	Elev. (m)
BPP	Silty	Enfield	Conifers	Coarse-silty over sandy, mixed, active, mesic Typic Dystrudepts	131	10.13	41.4792	-71.5636	32.6
PHR	Silty	Enfield	Conifers	Coarse-silty over sandy, mixed, active, mesic Typic Dystrudepts	125	10.19	41.4674	-71.6870	28.8
YWC	Silty	Bridgehampton	Conifers	Coarse-silty, mixed, active, mesic Typic Dystrudepts	131	10.05	41.5092	-71.5687	40.9
BPD	Silty	Enfield	Hardwoods	Coarse-silty over sandy, mixed, active, mesic Typic Dystrudepts	131	10.15	41.4777	-71.5619	31.5
KPE	Silty	Enfield	Hardwoods	Coarse-silty over sandy, mixed, active, mesic Typic Dystrudepts	131	10.13	41.4872	-71.5695	33.1
LAR	Silty	Enfield	Hardwoods	Coarse-silty over sandy, mixed, active, mesic Typic Dystrudepts	131	10.17	41.4659	-71.5565	30.6
BZM	Sandy	Merrimac	Conifers	Sandy, mixed, active, mesic Typic Dystrudepts	123	10.22	41.5445	-71.7173	44.2
FPC	Sandy	Merrimac	Conifers	Sandy, mixed, active, mesic Typic Dystrudepts	124	9.74	41.6326	-71.6406	108.6
PTC	Sandy	Merrimac	Conifers	Sandy, mixed, active, mesic Typic Dystrudepts	126	10.15	41.4716	-71.6656	27.7
GST	Sandy	Merrimac	Hardwoods	Sandy, mixed, active, mesic Typic Dystrudepts	123	10.39	41.5379	-71.4429	13.0
HAM	Sandy	Merrimac	Hardwoods	Sandy, mixed, active, mesic Typic Dystrudepts	123	10.33	41.5446	-71.4525	17.2
PEC	Sandy	Merrimac	Hardwoods	Sandy, mixed, active, mesic Typic Dystrudepts	131	10.12	41.4743	-71.5443	32.2
YWH	Silty	Enfield	Selective Harvest	Coarse-silty over sandy, mixed, active, mesic Typic Dystrudepts	131	10.05	41.5091	-71.5678	43.8
FPH	Sandy	Merrimac	Selective Harvest	Sandy, mixed, active, mesic Typic Dystrudepts	124	9.74	41.6326	-71.6411	102.8
PTH	Sandy	Merrimac	Selective Harvest	Sandy, mixed, active, mesic Typic Dystrudepts	127	9.80	41.8467	-71.6018	92.4
BZW	Mineral	Walpole	Riparian	Sandy, mixed, mesic Typic Humaquepts	123	10.30	41.5483	-71.7161	36.7
GRW	Mineral	Walpole	Riparian	Sandy, mixed, mesic, Typic Humaquepts	124	10.03	41.5431	-71.6853	52.4
KPW	Mineral	Walpole	Riparian	Sandy, mixed, mesic, Aeric Endoaquepts	131	10.13	41.4859	-71.5690	31.2
HLS	Organic	Scarboro	Riparian	Sandy, mixed, mesic Histic Humaquepts	128	9.93	41.5113	-71.6417	41.2
VRS	Organic	Scarboro	Riparian	Sandy, mixed, mesic Typic Humaquepts	127	9.75	41.5365	-71.6396	73.4
BZS	Organic	Scarboro	Riparian	Sandy, mixed, mesic Histic Humaquepts	123	10.30	41.5490	-71.7201	38.3

TABLE 1.2: Summary and results of two-way ANOVA on upland forest soil properties. Values for each horizon were weighted by the thickness and averaged for the upper 50 cm. vcos=very coarse sand, cos=coarse sand, ms=medium sand, fs=fine sand, vfs=very fine sand. CF=coarse fragment, BD=bulk density. P-values in bold represent significant difference was detected.

	Soil		**Cover**		**Two-way ANOVA P-value**		
	Merrimac	**Enfield**	**Coniferous**	**Deciduous**	**Soil**	**Cover**	**Soil x Cover**
Sand (%)	61.3 (9.4)	26.4 (7.1)	41.5 (17.4)	46.2 (23.5)	**<0.001**	0.37	0.41
Silt (%)	36.9 (9.1)	67.3 (7.7)	54.5 (15.2)	49.7 (21.2)	**<0.001**	0.36	0.47
Clay (%)	1.8 (0.4)	6.3 (1.3)	4.0 (2.3)	4.1 (3.0)	**<0.001**	0.8	0.52
vcos (%)	6.2 (4.3)	1.4 (0.7)	3.0 (3.4)	4.6 (4.4)	**0.04**	0.42	0.76
cos (%)	13.5 (8.0)	3.4 (1.7)	6.3 (4.2)	10.6 (9.9)	**0.01**	0.18	0.16
ms (%)	18.3 (4.3)	4.8 (2.1)	11.0 (8.2)	12.1 (8.0)	**<0.001**	0.62	0.88
fs (%)	12.2 (2.5)	4.4 (1.5)	9.1 (5.0)	7.4 (4.2)	**<0.001**	0.16	0.32
vfs (%)	10.4 (5.4)	13.1 (3.6)	12.4 (4.7)	11.1 (4.7)	0.381	0.65	0.85
CF (%)	7.7 (8.0)	2.8 (1.9)	5.3 (4.0)	5.1 (8.1)	0.231	0.96	0.83
Moisture (%)	17 (4)	20 (9)	18 (9)	18 (5)	0.5	0.95	0.59
Bulk Density (g cm^{-3})	1.00 (0.10)	0.88 (0.09)	0.92 (0.09)	0.96 (0.13)	0.08	0.95	0.54

TABLE 1.2 (Continued): SOM= soil organic matter, SOC=soil organic carbon, SOM:SOC = SOM to SOC ratio, C:N=carbon to nitrogen ratio.

	Soil		**Cover**		**Two-way ANOVA p-value**		
	Merrimac	**Enfield**	**Coniferous**	**Deciduous**	**Soil**	**Cover**	**Soil x Cover**
1:1 pH	3.96 (0.12)	4.13 (0.10)	4.00 (0.15)	4.09 (0.11)	**0.03**	0.16	0.67
SOM (%)	9.54 (1.70)	10.51 (2.95)	10.78 (3.01)	9.28 (1.31)	0.52	0.33	0.80
SOC (%)	4.75 (0.85)	4.48 (1.07)	4.69 (1.06)	4.54 (0.89)	0.66	0.82	0.54
Nitrogen (%)	0.24 (0.06)	0.23 (0.04)	0.23 (0.05)	0.24 (0.06)	0.65	0.74	0.18
SOM:SOC	2.5 (0.7)	3.3 (1.2)	3.3 (1.3)	2.4 (0.4)	0.15	0.13	0.36
C:N	13.5 (6.4)	16.5 (4.4)	16.5 (4.3)	13.5 (6.4)	0.39	0.39	0.97
SOC Pool (Mg ha^{-1})	109.2 (33.4)	101.0 (20.1)	106.3 (32.4)	103.9 (22.4)	0.66	0.89	0.93

TABLE 1.3: Summary of riparian forest soil properties and t-test results. Values for each horizon were weighted by the thickness and averaged for the upper 50 cm. vcos=very coarse sand, cos=coarse sand, ms=medium sand, fs=fine sand, vfs=very fine sand. CF=coarse fragments, BD=bulk density. P-values in bold represent significant difference was detected in paired t-test (N=6).

	Walpole		**Scarboro**		**Comparison**	
Variable	**M**	**SD**	**M**	**SD**	**t**	**P**
Sand (%)	65.1	15.5	91.6	8.3	-2.61	0.06
Silt (%)	25.5	9.7	8.0	7.7	2.45	0.07
Clay (%)	3.0	0.9	0.4	0.6	4.04	**0.02**
vcos (%)	8.9	7.4	37.4	24.4	-1.94	0.12
cos (%)	15.3	9.4	23.9	5.9	-1.33	0.26
ms (%)	18.1	5.0	16.3	16.4	0.18	0.86
fs (%)	12.4	2.9	11.4	14.7	0.11	0.92
vfs (%)	10.2	5.7	2.3	1.9	2.26	0.09
CF (%)	17.5	19.4	22.4	20.5	-0.30	0.78
Moisture (%)	27	9	45	3	-3.25	**0.03**
Bulk Density ($g\ cm^{-3}$)	0.76	0.10	0.62	0.13	1.50	0.21
1:1 pH	4.40	0.80	4.46	0.23	-0.13	0.91
SOM (%)	10.31	4.98	20.32	3.96	-2.72	0.05
SOC (%)	5.31	2.17	12.25	3.56	-2.88	**0.05**
Nitrogen (%)	0.29	0.13	0.68	0.11	-4.02	**0.02**
SOM:SOC	1.9	0.6	1.6	0.4	0.65	0.55
C:N	16.4	4.2	15.3	5.3	0.28	0.79
SOC Pool ($Mg\ ha^{-1}$)	116.0	19.3	210.2	94.3	-1.70	0.17

Table 1.4: T-test results and summary of selected dynamic properties compared between selectively harvested sites and paired controls. Litter, deadfall, and emergent vegetation data were averaged using data from 2012 and 2013 data. P-values in bold indicate a significant difference between the harvested treatment and the control (N=6).

Variable	Enfield		Merrimac				Control		Harvested		Comparison	
	YWC	YWH	PTC	PTH	FPC	FPH						
	Control	Harvested	Control	Harvested	Control	Harvested	AVG	STDEV	AVG	STDEV	t	p
Litter ($Mg\ ha^{-1}\ yr^{-1}$)	5.46	3.56	4.02	3.44	4.73	3.20	4.74	0.72	3.40	0.19	3.094	**0.036**
Deadfall ($Mg\ ha^{-1}\ yr^{-1}$)	0.33	0.55	0.39	0.14	0.16	0.14	0.29	0.12	0.27	0.24	0.133	0.9
Emergent Vegetation ($Mg\ ha^{-1}\ yr^{-1}$)	0.00	0.01	0.01	0.01	0.01	0.06	0.00	0.00	0.03	0.03	-1.325	0.256
O horizon thickness (cm)	4.35	3.65	2.85	2.65	3.55	3.55	3.58	0.75	3.28	0.55	0.558	0.607
50 cm SOC Pool ($Mg\ C\ ha^{-1}$)	75.51	95.07	154.91	84.78	106.64	120.80	112.36	40.01	100.22	18.55	0.477	0.658
Carbon (%)	4.61	4.84	4.79	3.14	5.35	5.87	4.91	0.38	4.62	1.38	0.362	0.736
Nitrogen (%)	0.22	0.26	0.28	0.18	0.30	0.28	0.27	0.04	0.24	0.05	0.701	0.522
pH (1:1)	3.96	4.07	3.79	4.34	3.86	4.06	3.87	0.09	4.15	0.16	-2.71	0.054

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Table 1.5: Multiple pairwise comparison (Tukey's) results on biomass and soil respiration compared between plots used in nitrogen enrichment experiment. Root biomass was measured using in-growth cores at 5-20 cm below the soil surface (Ricker et al., 2014). P values in bold indicate a significant difference between the treatment and the control. N=9.

Variable	Treatment	HLS	BZS	VRS	Mean	STDEV	Comparison	
							t	P
Root Biomass (Mg ha^{-1})	Control	0.56	0.93	0.46	0.65	0.25	-	-
	Low	1.99	1.27	1.85	1.70	0.38	1.727	0.135
	High	4.17	4.47	2.24	3.63	1.21	4.880	**0.006**
2013 Emergent Vegetation (Mg ha^{-1} yr^{-1})	Control	1.40	1.69	1.00	1.37	0.35	-	-
	Low	1.83	1.98	1.00	1.60	0.53	2.469	1.330
	High	1.84	2.08	1.11	1.68	0.51	3.252	0.091
2014 Emergent Vegetation (Mg ha^{-1} yr^{-1})	Control	1.40	1.27	0.53	1.07	0.47	-	-
	Low	2.00	2.04	0.74	1.59	0.74	2.889	0.128
	High	1.58	2.12	0.80	1.50	0.66	2.380	0.146
Average Soil Respiration Rate (g CO_2 m^{-2} hr^{-1})	Control	0.32	0.31	0.23	0.29	0.05	-	-
	Low	0.30	0.33	0.20	0.28	0.07	0.200	0.851
	High	0.54	0.31	0.28	0.37	0.14	-1.036	0.359

FIGURES

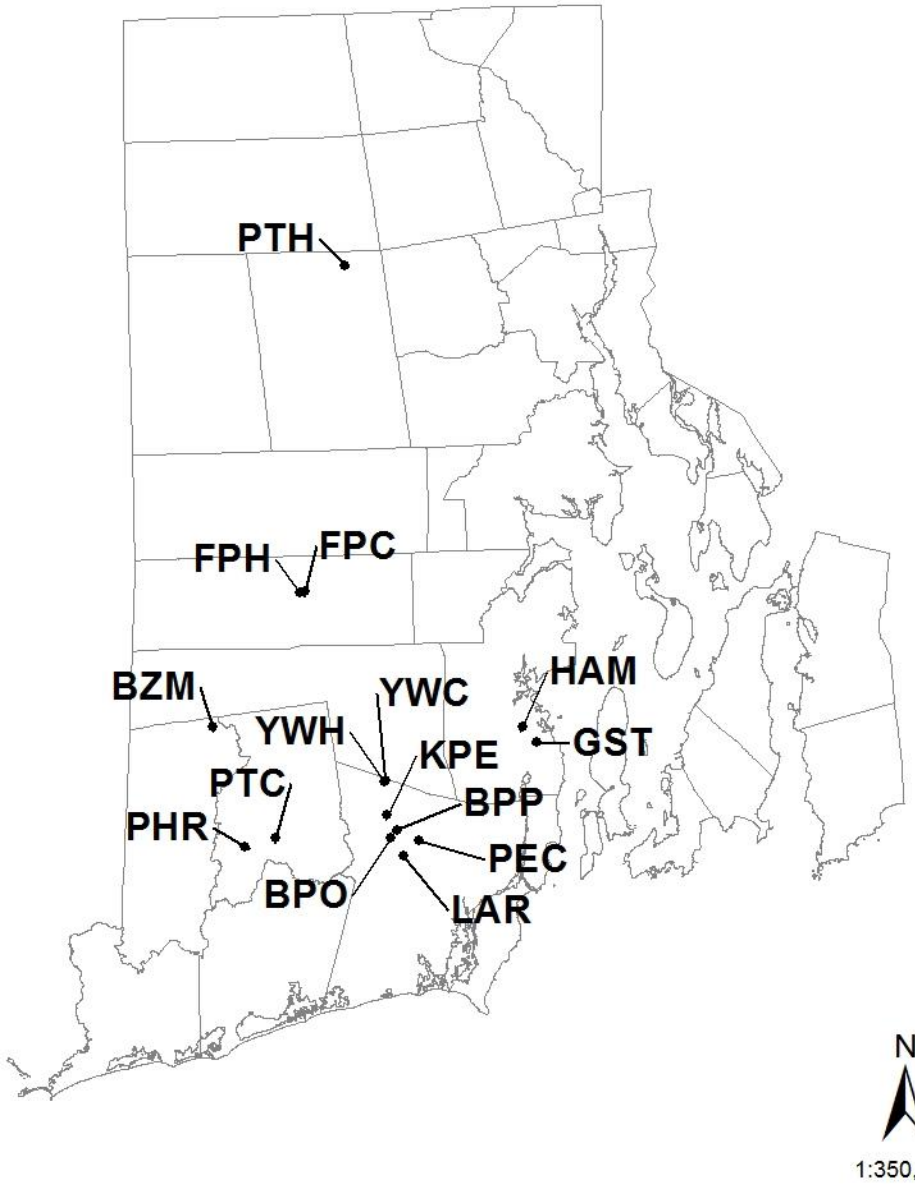


Figure 1.1: Upland site map. Sites were used for ecological site determination and were mapped as Merrimac or Enfield soil map unit consociations (Table 1.1). FPH, FPC, YWH, YWC, PTH, and PTC were used in the selective harvesting comparative study. Lines represent county boundaries.

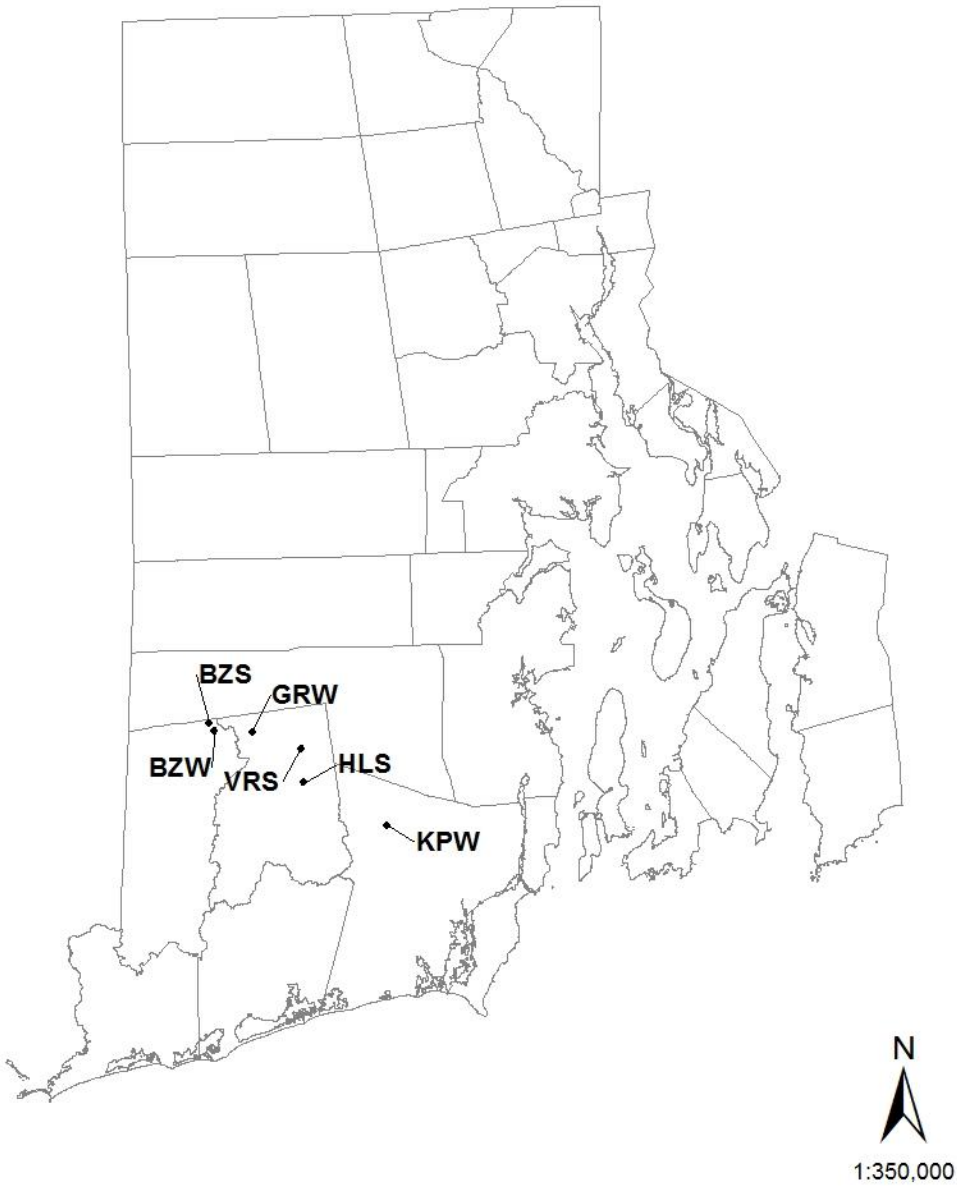


Figure 1.2: Location of riparian sites used for ecological site determination. BZW, KPW, and GRW were mapped as Walpole. BZS, HLS, and VRS were mapped as Scarboro and were also used in the riparian nitrogen enrichment experiment. Lines represent county boundaries.

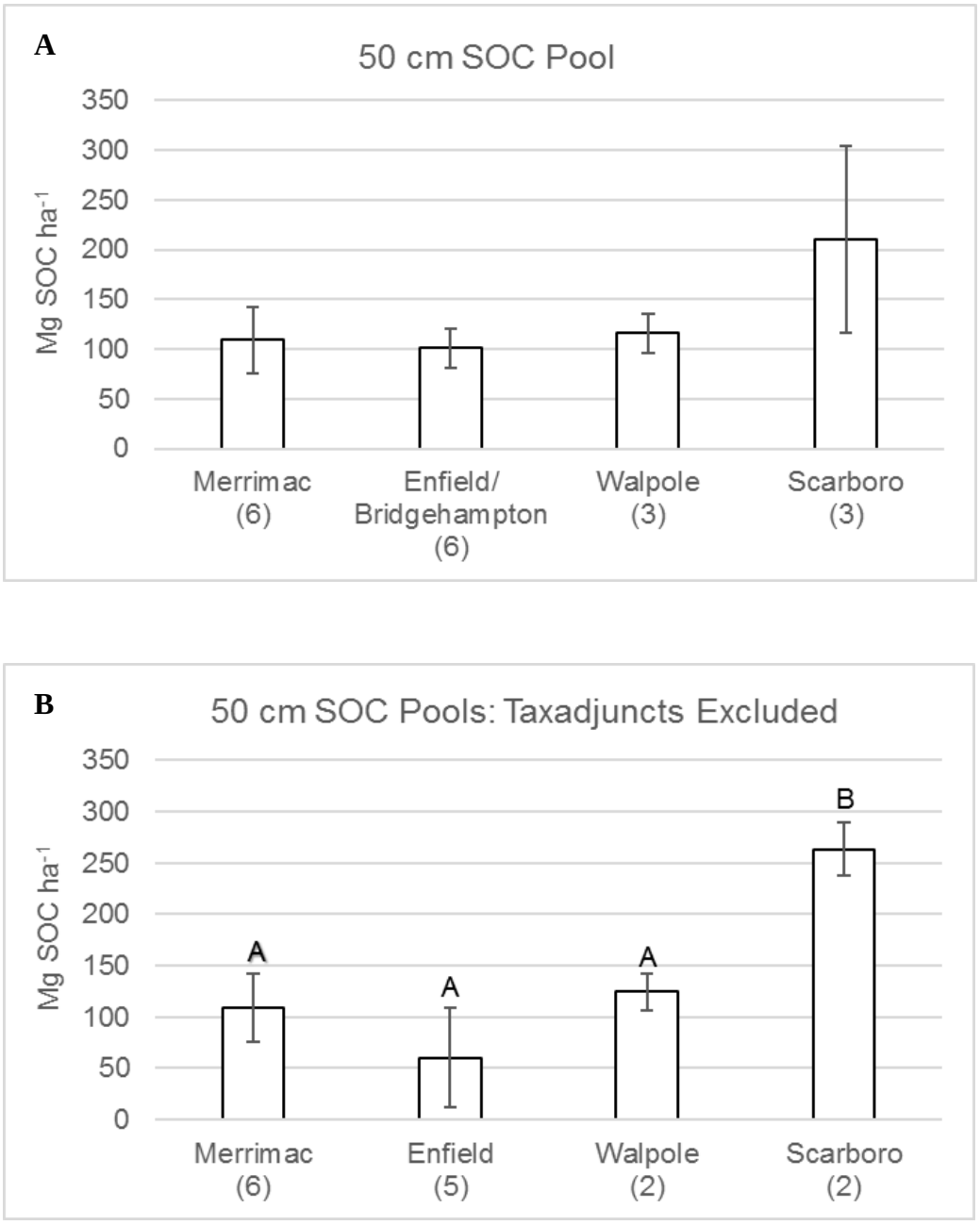


FIGURE 1.3. Soil organic carbon pools calculated for the upper 50 cm of upland and riparian soils. A) Taxadjucts and similar soils included. No significant differences between soil types were detected ($p = >0.05$). B) Sites YWC, KPW, and VRS did not meet the classification of their mapped series and were excluded from the analysis. Letters represent significant difference ($p = <0.05$).

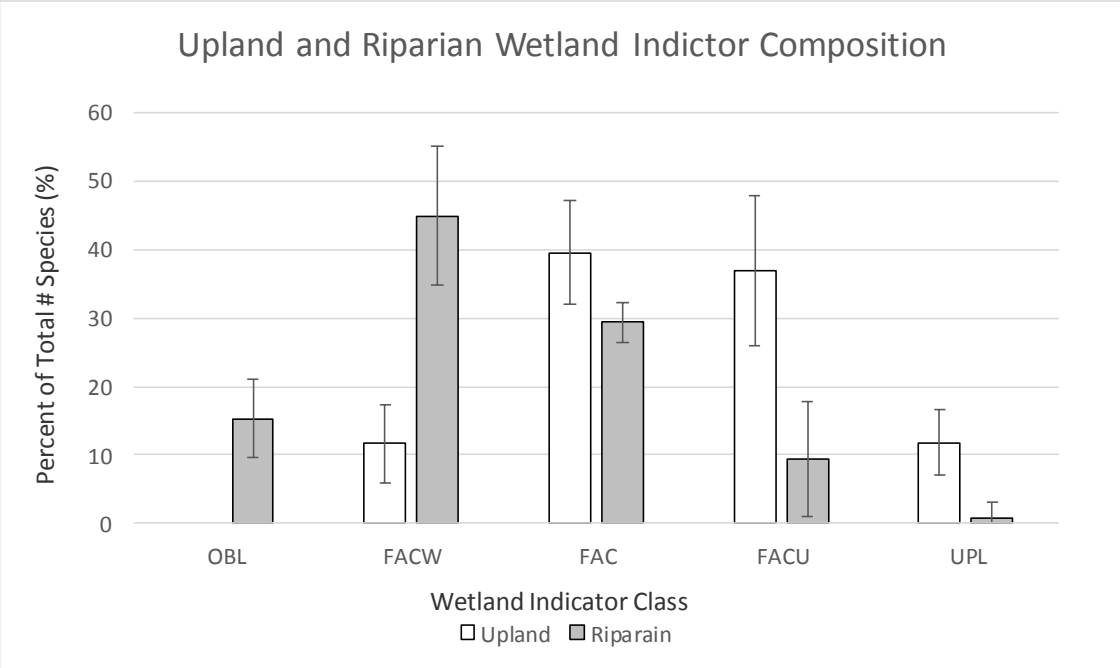


FIGURE 1.4: Composition of wetland indicator species for upland (12) and riparian (6) soils. A percentage is reported for each indicator class that was calculated from the total number of species. A significant difference was detected between upland and riparian sites for all indicator classes. Indicator classes determined from the National Wetland Plant List (Lichvar, 2012).

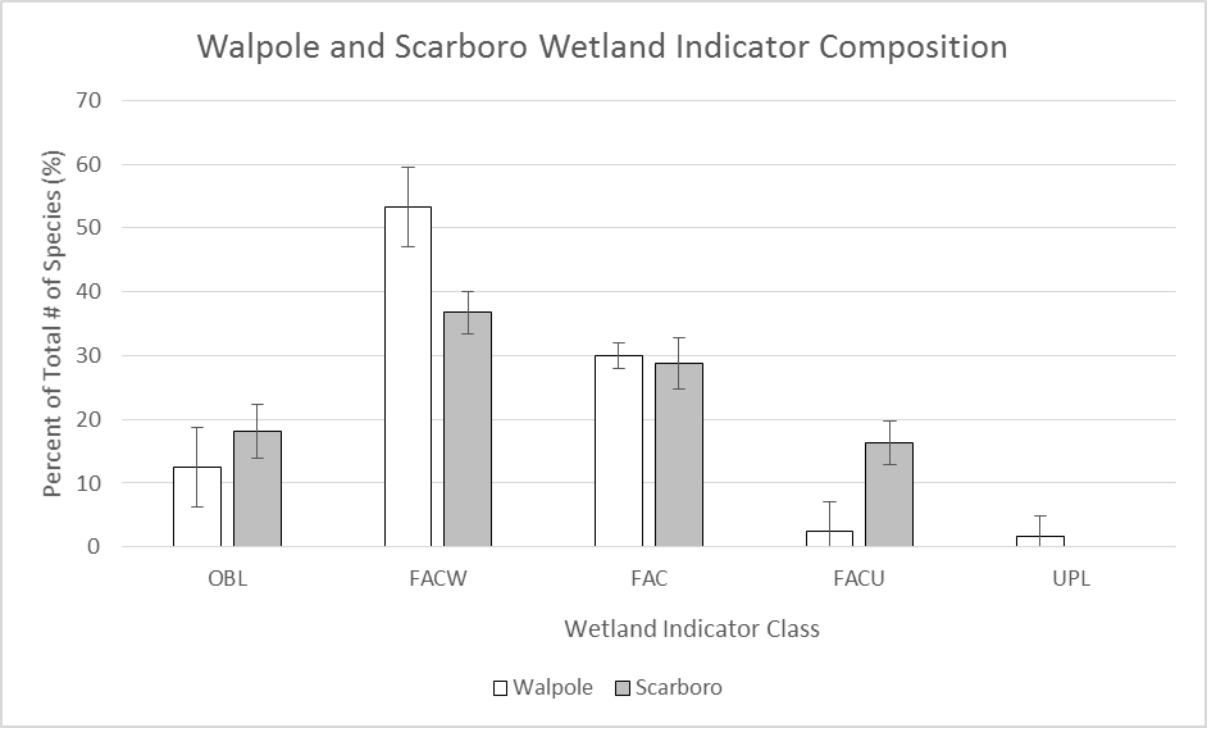


FIGURE 1.5: Composition of wetland indicator species for Walpole (3) and Scarboro (3) sites. A percentage is reported for each indicator class that was calculated from the total number of species. Walpole sites had significantly more FACW (p=0.016) and less FACU species (p=0.016), but this difference cannot be explained since Scarboro soils are wetter (very poorly drained). Indicator classes determined from the National Wetland Plant List (Lichvar, 2014).

CHAPTER 2: SOIL-VEGETATION DYNAMICS RELATIVE TO HUMAN DISTURBANCE IN ESTUARINE INTERTIDAL AND SUBTIDAL WETLANDS

ABSTRACT

The primary objective of this study was to initiate provisional ecological site concepts for estuarine subaqueous (subtidal) and salt marsh (intertidal) soils in southern New England. For both subaqueous and salt marsh soil types, I also determined how a specific disturbance or management scenario affected dynamic soil properties. In salt marshes, Ipswich (Histosols) and Matunuck (Entisols) soils were observed to determine how these soils respond to ditching and whether or not they are different ecological sites. Based on the kind of vegetation present, and the response of the vegetation to salt marsh ditching, these soils are the same ecological site. On both soils, *Spartina patens* and tall *Spartina alterniflora* were most common at or near the edge of the ditch and short *S. alterniflora* and salt marsh pannes occupied zones inward from the ditch. The productivity and distribution of individual salt marsh species is based on soil salinity, which is often a function of the distance of the pedon to the marsh-water interface. Four passive open-topped warming chambers (OTCs) were installed on an Ipswich soil to determine how increased temperature will effect soil carbon dynamics. I concluded that OTCs can successfully increase air temperatures by an average of 0.9 °C, but modifications to the design used in this study may be necessary to achieve projected temperature increases. Post-season biomass was 32% greater in the OTC plots in 2012 ($p=0.06$) and 91% more in 2013 ($p=0.01$), suggesting higher temperatures could increase productivity in salt marshes

with Ipswich soils. This increase in carbon additions to the soil may be offset by increased decomposition. This assumption was not supported by my soil respiration measurements, which showed no difference between warmed and control plots. I used macroinvertebrate distributions to compare Massapog and Pishagqua soils to illustrate that subaqueous soils can be viewed through an ESD framework. Massapog soils are part of the flood-tidal delta, a high energy environment near the estuary's inlet. The soils are sandier and have less SOM compared to the Pishagqua soils, which form on the bay floor, an area protected from high energy deposition. Within the upper 50 cm, Pishagqua soils averaged 73 Mg SOC ha^{-1} whereas Massapog soils averaged 29 Mg SOC ha^{-1}. Most individuals (94%) observed in Massapog soils were filter feeders, where the community in the Pishagqua soils mostly consisted of deposit feeders (78%). The differences in soils and geomorphic setting likely influenced the carbon pools and resulted in the observed differences in macroinvertebrate assemblages of the two soil types. In both subaqueous soil types, invertebrate density was reduced in the dredged soils, with a 97% difference observed in Massapog and a 71% decrease in Pishagqua. In the Massapog soils, eelgrass colonization following dredging induced a shift from dominantly filter feeding organisms to deposit feeders. I found that water depth influences the presence of eelgrass. I believe that in most cases dredging lagoon bottom soils will inhibit their ability to support eelgrass because depth will be too great. In contrast, dredging in the flood-tidal delta could inhibit or induce eelgrass presence. For both Massapog and Pishagqua dredging increased depth which resulted in finer textures and greater SOC accumulation.

INTRODUCTION

Estuarine intertidal and subtidal wetlands are important components of coastal ecosystems as they provide services such as habitat for benthos, sinks for carbon and pollutants, and sites for recreational and commercial fisheries (Bradley and Stolt, 2006; O'Higgins et al., 2010; Wieski et al., 2010; Sousa et al., 2012). Although shoreline counties of the U.S. only account for 10% of the nation's total land area, the population of these counties has increased by 40% since 1970 and currently accounts for 39% of the total population (NOAA, 2013). Due to their close proximity to developed areas and their resource value, estuarine ecosystems are subject to a variety of anthropogenic disturbances. Coupled with their limited areal extent, these wetlands may be recognized as threatened in respect to their soils and associated ecosystem services (Drohan and Farnham, 2006). Inventorying and monitoring these systems is essential in order to understand and preserve the ecosystem services provided by tidal wetlands.

Subaqueous Soils and Dredging

Over the last two decades soil scientists have been studying shallow subtidal estuarine substrates as soil (Demas, 1993; Demas and Rabenhorst, 1999; Bradley and Stolt, 2003; Stolt and Rabenhorst, 2011). These substrates are recognized as subaqueous soils because they undergo pedogenesis (Demas and Rabenhorst, 1999) and support aquatic vegetation (Bradley and Stolt, 2003). Estuarine subaqueous soils occur in the subtidal zone of protected coves, bays, inlets, and lagoons (Bradley and Stolt, 2003). In a manner similar to subaerial soils, soil-landscape relationships exist in subaqueous environments (Demas and Rabenhorst, 1999; Bradley and Stolt, 2003).

These relationships have been used to classify subaqueous soils and map soil units within selected estuaries along the eastern U.S. (Demas, 1993; Bradley and Stolt, 2003; Payne, 2007; Stolt et al., 2011). Subaqueous soils provide valued ecological and economic services, and therefore soil interpretations have recently been developed such as suitability for shellfish aquaculture, eelgrass restoration, and upland placement of dredge materials (Pruett, 2010; Salisbury, 2010).

In estuarine subaqueous soils, anthropogenic alterations including dredging activities may influence ecosystem processes by altering soil dynamics. Studies have shown that dynamic soil properties such as organic matter content, pH, and particle size influence shellfish production, eelgrass distribution, and water quality (Bradley and Stolt, 2006; Payne, 2007; Salisbury, 2010). For example, Salisbury (2010) found a positive relationship between eastern oyster (*Crassostrea virginica*) growth rates and sand content of soils and a negative relationship between growth and organic carbon content. Likewise, a study on the relationship between particle size and flounder distribution revealed that small juvenile flounder (<40 mm) are selective of fine-grained habitats, while larger juveniles (>40 mm) preferred coarser grained soils (Phelan et al., 2001). Subaqueous soil dynamics are highly dependent on the amount of energy present in the system, which is often depth dependent. Low-energy depositional environments, such as lagoon bottom and bay-floor soils, tend to have a finer particle size distribution, whereas high-energy features, such as washover fans and flood tidal deltas, tend to have more sand and a coarser particle size distribution (Bradley and Stolt, 2003). Currently, no research has been done to quantify the

resistance and resilience of soil properties such as carbon content to dredging activities.

Estuarine Salt Marshes, Ditching, and Climate Change

Salt marsh soils are intertidal and often form on the fringe of brackish or saltwater estuaries at the land-water interface. Competition and plant physiological tolerances create distinct zones of plant cover in New England salt marshes (Bertness and Ellison, 1987). The low marsh is inundated by daily high tides and is typically dominated by the salt tolerant *Spartina alterniflora* (Bertness and Ellison, 1987; Bertness et al., 1992). The portion of the marsh that is only flooded during the highest tides, the high marsh, is typically covered by the less salt tolerant *Spartina patens* (Bertness and Ellison, 1987; Bertness et al., 1992). Tidal salt marshes are the nursery grounds for a range of estuarine fish and wildlife while providing ecosystem functions such as groundwater filtration, carbon sequestration, and upland storm protection (Nixon and Oviatt, 1973; Boesch and Turner, 1984; Valiela et al., 2000; Wieski et al., 2010; Sousa et al., 2012). Sea level rise, ditching, nutrient loading, and other human induced disturbances, however, have altered salt marsh plant community dynamics and ecosystem services (Gedan et al., 2009). Therefore, it is critical to monitor the impact of anthropogenic effects and disturbances to salt marsh soil ecosystems.

Humans have been ditching New England salt marshes since the early 17th century to increase yields of *S. patens* and to mark property boundaries (Rozsa, 1995). During the early 18th century land managers increased ditching practices with the intention to drain pools at the soil surface, potentially eliminating mosquito larval habitat (Resh and Balling, 1983; Rozsa, 1995). Ditches have also been constructed to

increase tidal flooding to the marsh providing access for predatory fish (Resh and Balling, 1983). Previous ditching practices have led to changes in tidal inundation patterns which has resulted in changes in soil properties which influence salt marsh plant composition (Resh and Balling, 1983; Vincent et al., 2013a; 2013b). In a study on the Pacific coast, Resh and Balling (1983) found that only soils within 4 m of the ditch were drained and recharged by daily high tides. The change in the hydrology at ditched marshes resulted in a salinity gradient which increases with distance from ditch (Resh and Balling, 1983). Vincent et al. (2013a) noted that these changes in soil conditions influence the distribution of salt marsh vegetation. For example *Salicornia europea* and short-form *S. alterniflora* occupy zones outward from the ditch margin where sulfide accumulation and highly reduced conditions prohibit the colonization of high salinity intolerable species such as *S. patens* (Vincent et al., 2013a; 2013b). How ditching affects other dynamic soil properties that influence important ecological processes is presently unknown.

Climate warming is another factor which may influence salt marsh soil and vegetation dynamics. Global climate models project global surface temperatures to increase 1.5 to 4 °C by 2100 (IPCC, 2007). Projected surface temperature increases have been simulated using passive open-top warming chambers (Marion 1996; Marion et al., 1997; Gedan and Bertness, 2009; Gedan and Bertness, 2010). These chambers trap air near the soil surface, stimulating the greenhouse effect by increasing soil temperature as much as 3 °C (Marion 1996; Marion et al., 1997). Surface temperatures have been shown to influence vegetation community assemblages and biogeochemical cycles in salt marshes (Gedan and Bertness, 2009; Gedan and Bertness, 2010). Total

soil respiration is the result of the production of CO_2 from microbial decomposition, diffusion through culms, and root and rhizome respiration (Howes et al., 1985; Wigand et al., 2009). Richardson (2006) and Davis et al. (2010) found a positive correlation between temperature and soil respiration in New England forested uplands and palustrine wetlands. How such an increase in soil temperature will affect soil carbon dynamics in salt marshes is in question. Soil temperature increase may stimulate respiration from microbial decomposition, but this increase may be surpassed by CO_2 uptake from increased aboveground biomass production (Chumura et al., 2003; Davidson and Janssens, 2006).

Ecological Site Descriptions

The Natural Resource Conservation Service (NRCS) ecological site inventory is a framework developed for inventorying soil, vegetation, and abiotic features; delineating landscape scale units that share similar responses to management activities or disturbance processes; and estimating ecosystem services that can be expected from particular soil/vegetation combinations (Townsend, 2010). An ecological site is a defined as a distinctive kind of land having recurring soil, landform, geological, and climate characteristics that produces distinctive kinds and amounts of vegetation, and responds similarly to management actions and natural disturbances (NRCS, 2013). Soil-landscape units can be used for distinguishing ecological sites in these systems because they provide a mechanism for grouping soils that occur in a similar landscape setting. Within each ecological site, management or disturbance is the mechanism which changes soil-vegetation dynamics away from a referenced community resulting in different "states" (Briske et al., 2005). Thus, an ecological site is composed of a

reference community and a series of states that have transitioned from the reference state. Currently, no ESDs exist for subaqueous systems or salt marshes.

The objectives of this study were: i) to identify concepts for distinguishing ecological sites in selected salt marsh and subaqueous soils, ii) to quantify the effects of dredging, ditching, and warming on soil and vegetation dynamics of these ecosystems, and iii) to elucidate the effect of soil-vegetation community relationships relative to dynamic soil properties.

METHODOLOGY

Study Sites

Subaqueous Sites

The effect of dredging activities on dynamic soil properties in subaqueous soils were investigated in Mill Cove, Point Judith Pond, and Ninigret Pond (Figure 2.1). Sampling locations within each site were paired having both a dredged and adjacent control area. Dredged areas were mapped as the prevailing subaqueous soil series used for the adjacent control. Mill Cove is a brackish embayment located in North Kingstown, RI and is part of Wickford Harbor. Soil materials were removed from the dredged site for boat ramp access prior to mapping by Payne in 2007. Both the dredged and control soil units were mapped as the Pishagqua series (fine-silty, mixed, superactive, nonacid, mesic Fluventic Sulfiwassents). These soils are derived from estuarine deposits and are part of a low energy soil-landscape unit defined by Payne (2007) as the bay floor.

Ninigret Pond, also referred to as Charlestown Pond, is coastal lagoon isolated from the Block Island Sound by a barrier spit. In the 1950s, a breachway was constructed in order to maintain boat traffic into the pond, which increased tidal force and thus sedimentation (Conover, 1961). Soil materials from the breachway channel were removed to maintain navigable waters in 2008 along with material from the sedimentation basin for eelgrass restoration (Figure 2.1). Both the control and dredged areas are part of the flood-tidal delta flat (Bradley and Stolt, 2003). Dense eelgrass (*Zostera marina*) beds (>95% cover) occupy the dredged site whereas the control site

is totally barren. Soils in both of these areas were mapped as Massapog (fine-sandy, mixed, mesic Fluventic Psammowassents.

Subaqueous soils of Point Judith Pond were mapped by Mapcoast and the Natural Resource Conservation Service in 2010 (Mapcoast, 2010; Pruett, 2010). This pond also has a barrier spit, but differs from other estuaries in this study because it was formed from individual ice-block basins, which were flooded by sea level rise (Pruett, 2010). Point Judith is subject to daily boat traffic through a permanent inlet, which was created in 1909, to allow large vessels into the pond through the southern end (Jerusalem). Soils have been dredged to maintain traffic including a large channel to the west of Great Island, but the timing of dredging activities is uncertain. Similar to the Ninigret sites, this channel, along with the control site, are part of the flood-tidal delta flat and are mapped as Massapog.

Salt Marsh Sites

Ditched salt marshes along two Rhode Island estuaries: Pettaquamscutt (Narrow River) in Narragansett and Winnapaug Pond in Westerly were selected for investigation (Figure 2.2). These marshes were chosen because of notable differences in peat thickness between their marsh soil units, which may be a determining factor in the response of soil-vegetation dynamics to salt marsh ditching. Almost all salt marsh units of the two estuaries have been excessively ditched prior to 1934 (RIGIS, 2002). Marshes selected along the Narrow River are mapped as organic soils of the Pawcatuck series (sandy or sandy-skeletal, mixed, euic, mesic Terric Sulfihemists) but have inclusions of Ipswich soils (euic, mesic Typic Sulfihemists). The Winnapaug marshes are composed of mineral soils of the Matunuck series (sandy, mixed, mesic

Histic Sulfaquents). The difference in the morphology of these two soils is likely the result of their environmental setting (Wood et al., 1989). The Narrow River has small fluvial marshes occupying the upper margins of the estuary, whereas at Winnapaug the marshes occur behind the back-barrier component of the spit (Wood et al., 1989). Each site was investigated in an initial field reconnaissance to confirm soil types and to choose an area of the marsh for study.

Experimental Warming Site

Four pentagonal open-top warming chambers (OTCs) and four control plots, all 1 m^2, were installed at Fox Hill Salt Marsh on Conanicut Island located in lower Narragansett Bay (Figure 2.3). This marsh is a 10 ha transitional marsh and is relatively pristine in terms of nutrient loading (Wood et al., 1989; Wigand et al., 2009). OTCs (1 m diameter, 0.5 m height) were constructed out of 8 mm double-walled clear polycarbonate glass and aluminum double H extensions (Gedan and Bertness, 2010) and secured to the marsh soil-air interface with stainless steel cable and PVC stakes. OTCs were installed in June 2012, removed concluding the first growing season in November, washed, reinstalled in early May 2013, and then removed concluding the study in November 2013. The OTCs and control plots were designated in the high marsh zone where vegetation mainly consists of *Spartina patens* and soils are mapped as the Ipswich series (euic, mesic Typic Sulfihemist). The high marsh zone was selected for this experiment because OTC soil temperature increase may be limited in the low marsh zone where flooding occurs with high tides daily.

Sampling, Monitoring, and Laboratory Analysis

Dredging

Soil cores were collected from subaqueous soils using a Macaulay peat sampler in lagoon bottom soils (Wickford) and vibracore in sandy flood-tidal delta sites (Ninigret & Pt. Judith). Vibracores were sealed and stored in a walk-in refrigerator and described and separated by horizon in the lab. Macaulay samples were described and separated by horizon in the field (Schoeneberger et al., 2012) and transported to the lab in a cooler on ice. All soil samples were sealed in plastic sample bags and stored in a walk-in freezer at -15 °C until laboratory analysis to prevent the oxidation of sulfides (Twohig and Stolt, 2011).

In addition to the soil samples collected for characterization, five surface soil samples were collected at both the control and dredged sites at Wickford and Ninigret using a Petit Ponar sampler (2.2 L volume, sampling area 0.023 m^2) for macroinvertebrate inventory. Samples were passed through a 2.0 mm sieve and preserved in a 10% formalin solution containing rose Bengal dye until laboratory analysis. Benthic macroinvertebrates samples were sorted and identified to the species level when possible using basic dichotomous keys (Smith 1964; Weiss, 1995).

Salt Marsh Ditching

Within each estuary, three salt marsh ditches were chosen to capture the variability of soil properties and vegetation community attributes under study (Table 2.2). Two 15 m transects on each side and perpendicular to the ditch were established for sampling. Along the marsh ditch transects, sampling and field collection took place at distances of 0, 1, 5, and 15 meters from the ditch margin on either side of the ditch

(Figure 2.4). At each sampling point, vegetation composition was recorded as a percentage within a 0.25 m^2 quadrat and the average height and density of each species was recorded. Soil was collected and described in the field using a Macaulay peat sampler to 1 meter when possible (Bradley and Stolt, 2003; Twohig and Stolt, 2011). Peat thickness measurements were estimated by probing the soil with a metal rod. Relative surface elevations were also recorded using a rod and level along ditch transects. Marsh soil samples were stored in a freezer until analysis.

Soil Classification and Analysis

All laboratory soil analyses were conducted following standard soil survey methodology outlined in the Soil Survey Laboratory Methods Manual (Soil Survey Laboratory Staff, 2004). For each genetic horizon bulk density, soil organic carbon content, soil organic matter, initial and incubation pH, soil salinity, and particle size was determined. For organic samples rubbed fiber content was calculated for subordinate distinction determination. Calcium carbonate was also measured for subaqueous samples.

Bulk density was determined from Macaulay and vibracore samples taken from each horizon. Samples of a known volume were oven-dried at 105 °C. Oven-dry soil weight was divided by the volume yielding bulk density (g cm^{-3}). Soil organic matter content and calcium carbonate were determined via loss on ignition (LOI) (Heiri et al., 2001). Total organic carbon was calculated using organic matter LOI at 550 °C assuming an organic carbon-organic matter ratio of 0.5 (Nelson and Sommers, 1996; Pruett, 2010). Calcium carbonate was determined by subtracting the soil dry weight after combustion at 1000 °C from 550 °C dry weight and dividing the product

by the percent (59.95) of $CaCO_3$ that is lost as carbon dioxide through combustion (Heiri et al., 2001; Payne, 2007; Salisbury, 2010). Soil pH measurements were taken using an Accumet pH ATC combination electrode with silver/silver chloride reference. A 1:1 slurry of soil and water was mixed immediately after returning from the field or after stored sampled thawed for measurements. Moist conditions were maintained and incubation pH was recorded weekly for 16 weeks to determine potential acidity and identify sulfidic materials (Soil Survey Laboratory Staff, 2004; Payne, 2007). Soil salinity was measured in a 1:5 slurry of soil and water using an Oakton WD-35607 hand held conductivity meter (He et al., 2012). Particle size distribution was conducted using air dry soil from Macaulay and vibracore samples. Soil was wet sieved through a No. 270 standard sieve to determined sand content. Sands fractions were separated by dry sieving sand content samples on a sieve shaker for 5 minutes. Clay content was determined using the pipette method (Soil Survey Laboratory Staff, 2004; Payne, 2007). Silt content was calculated by subtracting the oven dry clay and sand weights from the total oven dry sample weight. Soil carbon pools were calculated for the upper 50 cm in Mg ha^{-1} using bulk density and carbon content parameters (Compton et al., 1998; Payne, 2007; Davis et al., 2010). Pedons were classified using Keys to Soil Taxonomy, 12th edition (Soil Survey Staff, 2014).

Experimental Warming of Salt Marsh Soils

Three core samples (98.2 cm^3) from the upper 15 cm and three 10 cm^2 vegetation samples were collected randomly in May 2013 (preseason) and at the peak of the growing season in August 2013 to determine biomass production (Windham, 2001; Gedan and Bertness, 2010). Vegetation samples were used to determine shoot

density, average shoot height, and total aboveground biomass (g cm^{-2}). Shoot density was calculated by counting the number of live shoots within each 10 cm^2 quadrate. A subsample of 30 shoots were measured to determine average height. All live shoots from each quadrate were dried in an oven at 60 °C for total aboveground biomass. Below ground biomass was determined by separating roots and rhizomes with tweezers, which were then soaked in a 0.5 g L^{-1} calgon solution, rinsed, and dried at 60 °C.

Thermochron iButton 1921G loggers with ±0.5 °C accuracy (Maxim Integrated Products, Sunnyvale, CA), were set to record soil and air temperatures hourly during the study period. Two loggers were installed in each plot, one 10 cm below the soil surface and one 15 cm above.

Soil CO_2 respiration losses were measured using the dynamic closed-chamber method (Rolston, 1986; Norman et al., 1997; Wigand et al., 2009; Davis et al., 2010). One 25 cm diameter PVC collar was installed 2.5 cm into the soil surface to form a seal and left for the duration of the study. In-situ soil CO_2 respiration losses were measured monthly at each plot using a Li-Cor 6262 infrared gas analyzer (Li-Cor, Lincoln, Nebraska), which was affixed to the PVC collars. Once sealed, CO_2 concentration was recorded from the analyzer every 10 seconds for a minimum of 5 minutes. To determine CO_2 efflux, a linear regression was fitted to the final 60-seconds of the measured CO_2 concentrations plotted as a function of time (Davis et al., 2010; Ricker et al., 2014). Pressure and temperature recorded from the analyzer along with the chamber volume were used to calculate moles of CO_2 per mole of air using

the Ideal Gas Law. The moles of CO_2 per mole of air was multiplied by the rate of CO_2 flux and divided by the chamber area to yield µmol CO_2 m^{-2} sec^{-1}.

Three nylon litter bags containing 5 g of clipped and oven dried aboveground vegetation, taken from onsite, were installed at the soil-air interface within each plot to estimate decomposition. Each bag was affixed to the soil prior to the growing season and removed in November. Following removal, partly decomposed materials were removed from each bag, rinsed and dried at 60 °C. Decomposition rates were plotted as a function of time using the difference between the initial oven dry weight of litter bag biomass and the oven dry weight of biomass following removal.

Statistical Analysis

Species composition and richness were calculated for the macroinvertebrate samples and each species was grouped into a functional feeding group (Weiss, 1995). The average density (individuals m^{-2}) and the total number of species within each feeding group were compared between treatments and soil types using paired t-tests. Soil data for subaqueous sites were weighted by horizon thickness and averaged for the upper 50 cm for comparison.

The upper 50 cm averages were also calculated for soils sampled for the ditching comparison. For each ditch, these attributes along with site and vegetation properties were averaged for each distance sampled from the ditch margin (0, 1, 5, and 15 meters). Analysis of variance (ANOVA) was used to detect differences between sampling locations within each soil type. For the warming experiment, paired t-tests were used to compare properties between warmed treatment and the control

RESULTS AND DISCUSSION

Subaqueous Soils and Dredging

Soil Characterization and Dynamic Soil Properties

At all three sites the particle size distribution was slightly finer in the dredged soil (Appendix 4). For a given landscape unit, increasing the water depth by dredging likely diminished flow rates relative to the adjacent natural soil and thus allowed for finer particles to settle out in the dredged areas. Although post dredging deposition was apparent, dredged sites always had greater water depth than the control (Table 2.1) suggesting that finer materials will continue to be deposited at the dredged areas.

The increase in depth may have promoted the growth of eelgrass in Ninigret Pond, and may have inhibited it in Point Judith Pond. At Ninigret Pond, the control site is quite shallow (0.5 m) and eelgrass is absent. Where dredging has increased depth to approximately 1.2 m, eelgrass is plentiful. The presence of eelgrass in the dredged site at Ninigret may in part also explain the slightly finer texture as eelgrass is known to trap sediment. The opposite trend between dredging and eelgrass was observed at Point Judith Pond (Table 2.1). Depth at the control site was 0.6 m and eelgrass cover was approximated at 90% cover. In the dredged channel, which was 3 m deep, there was no eelgrass. Bradley and Stolt (2006) found that eelgrass rarely occurred in southern New England subaqueous soils with water depths less than 50 cm or greater than 1.8 m.

Both Ninigret Pond sites were classified as Sulfic Psammowassents; having sulfidic materials within 100 cm of the mineral soil surface and a sandy family particle size class (Appendix 4). In both the control and dredged areas, buried horizons were

described at approximately 55 cm (Appendix 4). The slightly finer textures combined with the presence of eelgrass is likely the cause of greater carbon accumulation in the dredged soils. Soils having *Z. marina* exhibit greater carbon contents from the greater abundance of marine organisms and plant debris near the soil surface (Bradley and Stolt, 2006; Millar et al., 2015). The dredged soils also showed a larger change in pH following the 16 week incubation, which may indicate a greater accumulation of sulfides within the profile (Table 2.3A). Organic matter is required for sulfidization (Fanning et al., 2010) and the higher organic matter in the dredge material may have promoted the accumulation of sulfides resulting in lower incubation pH values in the Ninigret dredged soil. In contrast, although Payne (2007) found a significant positive relationship between organic carbon and total inorganic sulfide contents, the relationship between inorganic sulfide content and incubation pH was not significant. Payne (2007) argued that buffering of the pH from carbonates, clay, and organic matter may have confounded this relationship.

Similarly to the Ninigret soils, the Point Judith control pedon was classified as Sulfic Psammowassents (Appendix 4). However, the Point Judith dredged soil was classified as Sulfic Fluviwassents. Unlike the control site, the dredged soil at Point Judith had horizons finer than loamy fine sand within the control section (25-100 cm; Appendix 4). These dredged soils contained less sand (3.4%) and more silt (3.5%) and clay (0.1%) than their adjacent controls. Although both soils were dominated by fine sands, the dredged soil unexpectedly had more very coarse, coarse, and medium sand sized particles within the sand fraction. Point Judith dredged soils also had a greater bulk density, electrical conductivity, SOC and $CaCO_3$ pool than the control soils.

Greater pH change was observed in the control soils suggesting higher sulfide content or less pH buffering.

The Wickford Harbor control and dredged soils both averaged more than 18% clay within the control section and therefore classified as fine-loamy Typic Sulfiwassents (Appendix 4). Sulfiwassents, such as the Pishagqua series, are known to develop in low energy, soft-bottom landscape settings (Payne, 2007). The Pishagqua control soils at Wickford had almost twice the SOC compared to the Massapog control soils of the other two sites (Figure 2.5). Both the control and dredged soils at Wickford were dominated by fine sized particles although the dredged soils contained 30% more silt and 4% more clay than the adjacent control (Table 2.4). Sand content was much greater in the control soil (35%), but in both soils fine and very fine sands were most abundant. These soils exhibited dark colors and enough of a change in pH during the 16 week incubation to suggest sulfidic materials were present within the soil profile. Within the Wickford dredged soils, incubation pH change was 0.45 pH units greater than the change observed in the control soils (Table 2.3). Electrical conductivity, and SOC and $CaCO_3$, contents were also greater than the control. The Wickford dredged soils were also more fluid and had a lower bulk density than the control; likely the result of high SOM and low sand content in the dredged materials.

Subaqueous macroinvertebrate assemblages and ESDs

The Wickford and Ninigret dredged and control sites were chosen for ecological site comparison because they represent two common and recognizably different landforms in estuarine systems (Table 2.1; Figure 2.1). The different geomorphic settings of these sites results in contrasting soil types as mentioned in the

dynamic soil properties section above. The Massapog soils at Ninigret are part of the flood-tidal delta, a high energy environment near the estuary's inlet that is subject to additions of soil materials from storms and tidal fluctuations. The Pishagqua soils at Wickford formed on bay floor which is found in the interior of the estuary and are protected from high energy deposition. I found that Pishagqua soils are finer, more fluid, and have lower bulk density values than Massapog. Chemically, the Massapog soils have lower electrical conductivity and lower SOM and sulfide content. The contrast in their geomorphic setting and soil types was the basis for regarding them as separate ecological sites. Macroinvertebrate assemblages were analyzed in both the dredged and control sites at Ninigret and Wickford to determine if this was the case (Appendix 5).

Total invertebrate density and species richness were greatest at the Ninigret control site (Table 2.5). Of the twelve species observed at the Ninigret control, the majority (50%) were deposit feeders (Table 2.5). Although the deposit feeders were the most diverse community at the Ninigret control site, the majority of individuals were filter feeders with *Clymenella torquata* (common bamboo worm) as the most abundant species (Appendix 5). This non-motile species lives in tubes composed of cemented sand grains (Weiss, 1995). *C. torquata* is common to intertidal sandy mud flats and is widely distributed along the western coast of the Atlantic with densities reaching up to 150,000 m^{-2} (Sanders et al., 1962; Mach et al., 2012). Sanders et al. (1962) found an inverse relationship between *C. torquata* and bivalve abundance, although this trend was not observed in this study. *Mya arenaria* (soft-shell clam), a commercially important bivalve, was the second most abundant filter feeder species at

the Ninigret control site (409 m^{-2}). *M. arenaria* distribution is limited in highly fluid, fine grain soils which may collapse against shell valves (Abraham and Dillon, 1986).

Unlike the control, no filter feeders were found at the Ninigret dredged site. Although this was the case, *Clymenella torquata* tubes were present in the sample suggesting that *C. torquata* may be present at the dredged site as well. Deposit feeders were the most common community in the Ninigret dredged soil. *Nephtys picta* and species within the family Ampeliscidae were the most common individuals observed. Amphipods of the family Ampeliscidae dwell in sediment constructed tubes and have been documented to be a major prey item for juvenile winter flounder diet (Stehlik and Meise, 2000).

At both the Wickford control and dredge sites, *Ilyanassa obsolete* and *Gemma gemma* dominated benthic community composition (Appendix 5). *Ilyanassa obsolete* is a deposit feeding gastropod that is common on intertidal and shallow subtidal mud and sand flats (Weiss, 1995). This species was the most abundant species observed at the Wickford control site averaging 574 m^{-2}. Next in abundance at the control site, was *Gemma gemma* averaging 104 m^{-2}. Unlike the control site, more *Gemma gemma* (87 m^{-2}) were observed than *Ilyanassa obsolete* (61 m^{-2}) at the dredged site. *Gemma gemma* is a filter feeder common throughout New England estuaries that is a major constituent in the diet of shore birds during winter months (Sanders et al., 1952). Well sorted fine soils are preferred habitat for *Gemma gemma* because these soils retain seawater in pore spaces throughout low tides (Sanders et al., 1952).

In both subaqueous soil types, invertebrate density was reduced in the dredged soils (Table 2.5). This was unexpected for the Massapog soils since species richness

and abundance is typically greater in eelgrass habitats than in unvegetated soils (Heck et al., 1995; Lee et al., 2001). Van Houte-Howes et al. (2004) explained an edge effect that may occur adjacent to eelgrass bed, and that macroinvertebrates within the eelgrass bed may be limited by the dense mat of roots. The effect of dredging did not appear to have as much of an effect on the invertebrate community at Wickford. Both treatments at Wickford exhibited similar invertebrate composition, but differed in the distribution of individuals. The contrasting invertebrate communities observed between the Massapog and Pishagqua control sites is likely the result of their different geomorphic setting. Although these soils were dredged around the same time, the invertebrate assemblages of the Pishagqua soils observed at Wickford also seem to be more resilient to dredging. These two findings support the placement of these soils into different ecological sites.

Salt Marsh Ditching

Soil Characterization and Peat Thickness

The soils observed at Narrow River had organic soil materials greater than 130 cm (Figure 2.6) and therefore are more representative of the Ipswich series (euic, mesic Typic Sulfihemists), then the Pawcatuck series (sandy or sandy-skeletal, mixed, euic, mesic Terric Sulfihemists) that they were mapped as (Table 2.2). Peat thickness ranged from 120 to 185 cm and did not differ between sampling locations (Figure 2.6; $p=0.35$). At two sites peat thickness was greater further from the ditch, but at the third site (NR3) peat thickness initially increased and then decreased with distance (Figure 2.6).

The soils at Winnapaug are representative of the Matunuck series (sandy, mixed, mesic Histic Sulfaquents; Table 2.2). The thickness of the organic surface layer for this soil series ranges from 20 to 40 cm (Figure 2.6). Although some observations were slightly greater, the majority of peat thickness measurements at the Winnapaug marshes fit within this range. As observed at Narrow River, no relationship was determined between peat thickness ($p=0.99$) and the distance from the ditch (Figure 2.6).

Vegetation and ESDs

At the Narrow River marshes, no statistical differences were observed between species percent cover estimates, bare cover, or shoot density and the different distances from the ditch (Table 2.6). Although this was the case, several trends were observed. *Spartina patens* was a major occupier of zones 0, 1, and 5 meters from the ditch, but was never found dominating the 15 meter zone. *S. patens* height and stem density were also lowest 15 meters from the channel. At all three sites the highest percent cover and greatest average height of *Spartina alterniflora* was observed either at the edge of the ditch or in the 1 meter zone. *Distichlis spicata* and *Salicornia europaea* were also found at the three Narrow River marshes, but their abundance was minimal and no trends were observed with distance from the ditch.

Vegetation at the three Winnapaug sites was dominantly *S. alterniflora* (Table 2.6). Similarly to Narrow River, percent cover of this species was greatest near the edge of the ditch, but did not differ significantly between sampling locations. *S. alterniflora* shoot density was greater at the edge and 5 meters from the ditch ($p=0.02$). Likewise *S. alterniflora* height was greater at the edge and 1 meter zones

($p<0.01$). Bertness (1984) found that *S. alterniflora* production was greatest at the seaward edge of the marsh where mussel density and soil nitrogen levels are elevated. Although neither mussel density nor nitrogen were measured, I believe a similar effect occurs along the ditch margins.

Overall, Matunuck soils at Winnapaug sites averaged 25 percent more bare cover than the Ipswich soils at Narrow River, but the difference was statistically insignificant ($p=0.08$). Percent bare soil at the Winnapaug marshes was lowest near the edge of the ditch and often highest further from the channel. Total shoot density at the Winnapaug marshes was over 50% lower than at the Narrow River sites ($p=0.03$). The main contributor to the difference in total shoots was the density of *S. patens*, which had significantly lower average values at the Winnapaug marshes ($p=0.01$). Cover of *S. europaea* species was greatest at the Winnapaug marshes, where bare cover was greater than 80%. The high amount of bare soil in the Winnapaug marshes and presence of *S. europaea* is indicative high soil salinity, which prohibits the colonization of low salt tolerant species such as *S. patens* (Bertness et al., 1992). This also explains why *S. patens* was rarely found in the 15 meter zone at the Narrow River marshes. Plant height was observed to be similar between the Winnapaug and Narrow River sites.

Based on the kind of vegetation present, the Ipswich soils (Histosols) studied at Narrow River are the same ecological site as the Matunuck soils (Entisols) at Winnapaug. The data collected suggests that productivity and distribution of individual salt marsh species is based on soil salinity, which is often a function of the distance of the pedon to the marsh-water interface. Within a given soil map unit the

variability of soil salinity is too high to identify where salinity limits productivity. Therefore, I believe the different assemblages of salt marsh vegetation that were observed are community phases rather than different ecological sites, or separate states within one ecological site. The National Ecological Site Handbook defines a community phase as a unique assemblage of plants and associated dynamic soil properties that can develop over time within a state (NRCS, 2013). Unlike a state, the vegetation community phases reported at each location along the ditch transects could shift from one community to another over time due to slight alterations in tidal fluctuations, without management or disturbance. Therefore, one ecological site should encompass the salt marsh soils reported in this study.

Dynamic Soil Properties

As mentioned previously, the primary difference between the soils at Narrow Rivers (Ipswich) from those at Winnapaug (Matunuck) is the thickness of organic materials (Figure 2.6). Since the Narrow River soils contained a thick organic surface, average SOM was high (40.6%; Figure 2.7). I found that the organic materials at Narrow River were mainly composed of hemic soil materials averaging 22% rubbed fibers (Figure 2.7) with no significant differences between sampling points ($p=0.22$; Table 2.7). Differences in bulk density were observed at Narrow River between the different sampling distances ($p<0.01$), with bulk density decreasing with distance from ditch. I believe the decrease in bulk density with distance from the ditch margin was due to higher sand and lower SOM content near the ditch margin where deposition from daily high tides occurs. The trend in SOM with distance from the ditch supported this finding (Table 2.7), although the values were not statistically different between

sampling locations (p=0.102). At Narrow River, chemical properties including incubation pH, pH change, and electrical conductivity varied between sampling locations (Table 2.7). Incubation pH values were higher further from the ditch than near the ditch margin. It is possible that higher SOM further from the ditch buffered of the pH leading to this trend. At intermediate pH levels, SOM absorbs acid cations produced from the oxidation of sulfides in the soil. This leads to less change in pH over the 16 week incubation. Since the soils further from the ditch are not regularly flushed by tides, salt accumulation is likely the cause of higher electrical conductivity and more halophytes such as *S. europea* in this zone.

Based on field observations and lab characterization, the marine sediments underlying the organic surface of the Matunuck soils at Winnapaug were high in sand and low in organic matter (Figure 2.7). Lower SOM within the upper 50 cm strongly influence SOC pools, which for Matunuck averaged 123 Mg SOC/ha compared to the 210 Mg SOC/ha observed in the Ipswich soils (Figure 2.8). At the Winnapaug sites, SOM did not follow the same trend with distance from the ditch as observed at Narrow River (p=0.17). Unlike Narrow River, the organic materials sampled from the Matunuck soils at Winnapaug were primarily sapric, averaging 11% rubbed fiber. Since rubbed fiber volume can be an indicator of soil decomposition, the Matunuck soils observed in this study were more decomposed than the Ipswich soils. Less vegetation production at Winnapaug (Table 2.6) could limit the amount of organic matter additions to the soil, lowering the proportion of undecomposed (fibric) material in the soil profile. The lower vegetation production and higher bare cover at the Winnapaug marshes is likely the result of high soil salinity. Similar to the Narrow

River soils, electrical conductivity at Winnapaug increased with distance from the ditch margin (Table 2.7). Although both soils exhibited this trend, the average electrical conductivity of Matunuck soils at Winnapaug was 6.4 dS m^{-1}, which was significantly greater than the 3.4 dS m^{-1} average reported for the Ipswich soils at Narrow River ($p<0.01$). The higher electrical conductivity of the Winnapaug soils is likely because those sites are closer in proximity to the ocean, where the Narrow River marshes are more inland.

Experimental Warming of Salt Marsh Soils

Temperature

There was a significant increase in the average air temperature (0.9 °C) in marsh plots covered with OTCs compared to the control in 2012 ($p=0.03$). In 2013, average air temperature for the warmed treatment was 0.7 °C greater, but this increase was not deemed significantly different from the control ($p=0.20$). The difference in average monthly air temperature for the OTC plots was greatest in October 2012 (+1.7 °C) and lowest in June 2013 where air temperature for the warmed treatment measured 0.1 °C lower than the control (Table 2.8).

Average soil temperature over the entire study time period, was similar between the treatment and control ($p=0.06$). In 2012, average soil temperature was 0.5 °C greater for the control ($p=0.03$), but in 2013 the control and treatment exhibited similar soil temperatures ($p=0.57$). Although the chambers were washed between seasons, it was noted that the transparency of the glass used to make the panels had decreased. Thus, the differing results between years suggests that the chambers may have degraded after the first year. Alternatively, the biomass increase stimulated by

increased temperature in the fall months may have induced shading, decreasing temperatures.

Carbon Losses

Soil temperature showed a positive relationship to soil respiration ($p<0.01$), but the relationship was not as strong ($R^2=0.40$) as previously observed by Richardson (2006) and Davis et al. (2010) in forested systems. Although warmed plots exhibited higher respiration rates in several months, average soil respiration did not differ between the warmed and control treatment (Figure 2.9; $p=0.83$). Much of the soil respiration was hypothesized to be a function of plant decomposition. Thus, I used percent *S. patens* litter lost from the litter bags over time as a metric of decomposition. In both years, percent loss was greater for the warmed treatment than the control, but was not statistically significant ($p=0.114$). In 2012, litter bags were in situ for 107 days, and percent loss averaged 50.4% for the warmed treatment and 47.8% for the control. Similarly, bags were installed for 110 days in 2013, but percent loss was greater in the both the control (58.4%) and warmed treatment (65.1%) than in the previous year. These values are similar to those found by Charles and Dukes (2009) who also found that warming increased salt marsh grass decomposition.

Carbon Additions

Pre-season aboveground and belowground biomass, recorded in May 2013, was similar between the warmed plots and the control ($p=0.99$; Table 2.9; 2.10). Post-season aboveground biomass was 32% greater in the warmed plots in 2012 ($p=0.06$) and 91% more in 2013 ($p=0.01$). Post-season biomass was 72-87% live tissue and was greater in warmed plots in 2012 ($p=0.10$) and 2013 ($p=0.01$; Table 2.9). No significant

difference was observed in belowground biomass between the warmed and control plots (p=0.5; Table 2.10) suggesting that projected temperature increases will possibly only increase *S. patens* aboveground production possibly due to stronger warming by OTCs above the soil surface. Projected temperature increases with climate change may also impact belowground processes related to carbon, but the ability of OTCs to increase soil temperature seems insufficient.

These findings are consistent with Gedan and Bertness (2010) who also found that warming increases *S. patens* aboveground production. Contrasting to these results, Charles and Dukes (2009) did not observed an increase in *S. patens* production with experimental warming. Although that was the case, they did find that warming increased *S. alterniflora* production and *S. patens* stem length (Charles and Dukes, 2009). I also discovered that *S. patens* stems were significantly longer in the warmed plots than in the control (p=0.03; Table 2.9). Stem density measured in 2013 was also used as an indicator of *S. patens* production. Peak season stem density averaged 11,425 stems per m^2 for the warmed treatment, which was 28% more than the control, but not statistically different (p=0.166; Table 2.9). Increased stem density could lead to greater marsh accretion by trapping more sediment from tides, which would help salt marshes respond to projected seas level rise (Leonard and Croft, 2006; Charles and Duke, 2009).

SUMMARY AND CONCLUSIONS

In this study, I compared soils and vegetation between contrasting soil types of southern New England estuaries, and documented how these soils respond to different management scenarios. I used macroinvertebrate assemblages to illustrate that subaqueous soils can be viewed through an ESD framework. The invertebrate community observed on Massapog soils of Ninigret Pond was mostly composed of filter feeders. This community was distinguishable from the deposit feeder dominated community observed on the Pishagqua soils at Wickford. The differences observed between the Pishagqua and Massapog soils and invertebrate communities are the result of their different geomorphic setting. The Massapog soils are part of the flood-tidal delta, a high energy environment near the estuary's inlet. These soils are sandier and have less SOM compared to the Pishagqua soils, which form on the bay floor, an area protected from high energy deposition.

The response to dredging was also different between Pishagqua and Massapog soils. In both subaqueous soil types, invertebrate density was reduced in the dredged soils. Unlike the Pishagqua soils, the dominant functional feeding group of the Massapog soils was different between the control and dredged sites. For both Massapog and Pishagqua dredging increased depth which resulted in finer textures and greater SOC accumulation. The response of eelgrass presence to dredging agrees with the findings by Bradley and Stolt (2006), who noted that water depth influences the presence of eelgrass, likely because water depth influences light availability. I believe that in most cases dredging lagoon bottom soils will inhibit their ability to support

eelgrass because depth will be too great. In contrast, dredging in the flood-tidal delta could inhibit or induce eelgrass presence.

Two salt marsh soils, Ipswich and Matunuck, were observed in this study to determine how these soils respond to ditching and whether or not they are different ecological sites. Based on the kind of vegetation present, the Ipswich soils (Histosols) studied are the same ecological site as the Matunuck soils (Entisols). On both soils, *S. patens* and tall *S. alterniflora* were most common at or near the edge of the ditch and short *S. alterniflora* and salt marsh pannes occupied zones inward from the ditch. The productivity and distribution of individual salt marsh species is based on soil salinity, which is often a function of the distance of the pedon to the marsh-water interface. I believe the different assemblages of salt marsh vegetation that were observed are community phases rather than different ecological sites, or separate states within one ecological site. Unlike a state, the vegetation community phases reported at each location along the ditch transects could shift from one community to another over time, without management or disturbance. This hypothesis was not tested in this study, but should be a future consideration for any ecological site inventory that takes place in these systems. If this hypothesis is correct, one ecological site could encompass the salt marsh soils reported in this study.

After quantifying soil-vegetation dynamics in relation to salt marsh ditching, I concluded that in both soils only zones near the edge of the ditch receive deposition from daily high tides. This is explained by soils having greater bulk densities near the edge of the ditch and higher SOM content further from the ditch. Since only the portion of the marsh adjacent to the ditch receives deposition, in several cases a berm

formed along the edge of the ditch, which induces standing water on the marsh surface. This likely resulted in the higher electrical conductivity values observed further from the ditch and the formation of salt marsh pannes, where only stunted *S. alterniflora* and *S. europaea* could survive. My research suggests that similar plant communities can exist on soils with peat thicknesses ranging from 20-180 cm. I also found that Matunuck and Ipswich soils share a similar response to ditching. These two findings support one ecological site for salt marsh soils of the Ipswich, Pawkatuck, and Matunuck series.

Four warming chambers were installed in the high marsh on an Ipswich soil to determine how increased temperature will effect soil carbon dynamics. I concluded that passive open top warming chambers can successfully increase air temperatures, but modifications to the design used in this study may be necessary to achieve consistent, projected temperature increases. On average, soil temperatures were lower in the chambers. This was likely the result of shading by increased biomass and increased stem length. OTC plots had higher aboveground production, but this increase in carbon additions to the soil may be offset by increased decomposition. Since observed soil respiration rates were slightly correlated to temperature, increases in carbon additions to the soil could be offset by the higher decomposition rates, with a possible carbon transfer from soil to atmosphere. These effects should be further studied to understand the possible implications on salt marsh carbon budgets.

TABLES

Table 2.1: Summary of subaqueous study sites.

Site	Latitude	Longitude	Landform	Soil	Family Classification	Water Depth (m)	Eelgrass (%)
Ninigret Control	41.364987 N	71.636108 W	Flood-tidal delta	Massapog	Sulfic Psammowassents	0.5	0
Ninigret Dredged	41.365714 N	71.635572 W	Flood-tidal delta	Massapog	Sulfic Psammowassents	1.2	95
Point Judith Control	41.393661 N	71.507133 W	Flood-tidal delta	Massapog	Sulfic Psammowassents	0.6	90
Point Judith Dredged	41.393967 N	71.507759 W	Flood-tidal delta	Massapog	Sandy Sulfic Fluviwassents	3	0
Wickford Control	41.578878 N	71.451186 W	Bay floor	Pishagqua	Fine-loamy Typic Sulfiwassents	1	0
Wickford Dredged	41.579874 N	71.452021 W	Bay floor	Pishagqua	Fine-loamy Typic Sulfiwassents	3.7	0

Table 2.2: Summary of salt marsh study sites.

Site	Latitude	Longitude	Soil	Family Classification	Ditch Width (cm)	AVG Peat Thickness (cm)
Narrow River Ditch 1	41.48484 N	71.44803 W	Ipswich	Euic, mesic, Typic Sulfihemists	165	151.6
Narrow River Ditch 2	41.45285 N	71.45053 W	Ipswich	Euic, mesic, Typic Sulfihemists	235	171.9
Narrow River Ditch 3	41.45306 N	71.45464 W	Ipswich	Euic, mesic, Typic Sulfihemists	155	156.1
Winnapaug Ditch 1	41.32961 N	71.78237 W	Matunuck	Sandy, mixed, mesic Histic Sulfaquents	151	32.3
Winnapaug Ditch 2	41.33038 N	71.78136 W	Matunuck	Sandy, mixed, mesic Histic Sulfaquents	100	41.3
Winnapaug Ditch 3	41.33055 N	71.78058 W	Matunuck	Sandy, mixed, mesic Histic Sulfaquents	135	39.6
Fox Hill Salt Marsh	41.48976 N	71.39367 W	Ipswich	Euic, mesic, Typic Sulfihemists	NA	148

Table 2.3: Subaqueous soil properties. Horizon values were weighted by thickness. Averages were calculated for the upper 50 cm of the soil.

Site	Initial pH	Incubation pH	pH Change	EC (dS m^{-1})	SOM (%)	$CaCO_3$ (%)	Bulk Density (g/cm^3)
Ninigret Control	7.83	7.64	-0.19	1.61	0.48	0.46	1.21
Ninigret Dredged	6.66	3.49	-3.17	2.71	1.21	0.90	1.18
Point Judith Control	7.90	5.56	-2.34	1.35	0.81	0.76	1.04
Point Judith Dredged	7.83	8.32	0.49	2.41	1.24	1.05	1.36
Wickford Control	7.00	2.98	-4.02	3.38	4.82	3.45	0.86
Wickford Dredged	7.54	3.06	-4.47	4.97	7.61	4.95	0.28

Table 2.4: Subaqueous soil particle size distribution. Averages were calculated for the upper 50 cm of the soil.

Site	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	sand (%)	silt (%)	clay (%)
Ninigret Control	0.07	1.61	10.47	52.97	26.68	91.81	7.50	0.69
Ninigret Dredged	0.05	1.43	5.46	47.32	34.26	88.51	10.31	1.18
Point Judith Control	0.05	0.25	5.76	71.52	16.98	94.56	4.30	1.13
Point Judith Dredged	0.21	1.13	13.45	62.66	13.75	91.20	7.80	1.00
Wickford Control	0.74	3.36	9.32	14.43	18.11	45.96	35.99	18.05
Wickford Dredged	0.10	0.22	0.50	1.02	9.42	11.25	66.19	22.56

Table 2.5: Summary of soil macroinvertebrate assemblages compared between the Massapog soils found at the Ninigret site and the Pishagqua soils of Wickford. The total number of species (species richness) and mean density (individuals per m^2) are distinguished by functional feeding group.

Site	Deposit feeders		Filter feeders		Predators		Parasites		Species Richness	Total Density
	Species	Density	Species	Density	Species	Density	Species	Density		
Ninigret Control	6	278	3	5861	2	70	1	9	**12**	**6217**
Ninigret Dredge	3	148	1	0	1	26	0	0	**5**	**174**
Wickford Control	1	574	2	148	1	9	1	9	**5**	**739**
Wickford Dredge	2	70	2	130	1	9	1	9	**6**	**217**

Table 2.6: Salt marsh ditching percent cover, average stem density, and average stem height for dominant species observed at transect sampling locations. N=Narrow River; W=Winnapaug marsh.

Site	Distance from ditch (m)	% Bare soil	*Spartina patens*			*Spartina alterniflora*			*Distichlis spicata*			*Salicornia europaea*		
			Cover (%)	Stems m^2	Height (cm)	Cover (%)	Stems m^2	Height (cm)	Cover (%)	Stems m^2	Height (cm)	Cover (%)	Stems m^2	Height (cm)
N1	**0**	**13**	**83**	7450	40.7	**5**	700	59.3	**0**	0	0.0	**0**	0	0.0
	1	**20**	**48**	3600	31.3	**33**	750	42.8	**0**	0	0.0	**1**	50	16.0
	5	**55**	**18**	3350	22.7	**28**	2000	33.3	**0**	0	0.0	**0**	0	0.0
	15	**70**	**7**	1350	22.3	**24**	1600	16.2	**0**	0	0.0	**0**	0	0.0
N2	**0**	**48**	**17**	1750	25.3	**35**	1050	36.5	**1**	20	11.7	**1**	50	6.7
	1	**40**	**33**	3850	18.7	**25**	550	35.8	**1**	5	12.2	**3**	450	19.0
	5	**56**	**38**	5000	27.8	**5**	500	26.8	**1**	5	12.0	**1**	150	15.0
	15	**75**	**3**	150	8.7	**18**	1450	19.7	**0**	0	0.0	**5**	1300	8.7
N3	**0**	**40**	**16**	1650	31.5	**42**	700	56.0	**2**	30	43.0	**1**	50	13.0
	1	**66**	**25**	6050	41.0	**2**	100	47.2	**7**	230	38.3	**1**	50	17.5
	5	**65**	**34**	6200	42.5	**0**	0	0.0	**1**	35	40.5	**0**	0	0.0
	15	**58**	**4**	1400	12.5	**37**	1600	31.5	**1**	25	26.7	**1**	50	10.7
W1	**0**	**70**	**0**	0	0.0	**30**	800	49.3	**0**	0	0.0	**0**	0	0.0
	1	**80**	**3**	950	25.2	**17**	500	50.3	**0**	0	0.0	**1**	100	9.0
	5	**90**	**6**	1400	20.8	**4**	350	28.7	**0**	0	0.0	**1**	50	8.7
	15	**89**	**1**	1350	11.7	**8**	400	28.3	**0**	0	0.0	**3**	150	11.2
W2	**0**	**83**	**0**	0	0.0	**18**	750	56.0	**0**	0	0.0	**0**	0	0.0
	1	**90**	**2**	1250	18.5	**7**	550	47.7	**0**	0	0.0	**2**	250	13.7
	5	**82**	**15**	3700	12.7	**1**	50	14.0	**1**	50	12.5	**2**	250	19.3
	15	**85**	**0**	0	0.0	**11**	550	20.3	**0**	0	0.0	**5**	300	10.0
W3	**0**	**80**	**0**	0	0.0	**20**	750	56.0	**0**	0	0.0	**0**	0	0.0
	1	**92**	**2**	1050	20.2	**5**	450	43.7	**0**	0	0.0	**2**	250	13.8
	5	**94**	**0**	0	0.0	**3**	250	25.2	**0**	0	0.0	**3**	400	17.8
	15	**84**	**0**	0	0.0	**11**	550	18.5	**0**	0	0.0	**6**	350	18.2

Table 2.7: Salt marsh ditching soil properties averaged for upper 50 cm by sampling location. Incubation pH is the pH after 16 weeks of incubation.

Site	Distance from Ditch (m)	Fiber Content (%)	Rubbed Fibers (%)	Moisture (%)	Bulk Density (g/cm^3)	Initial pH	Incubation pH	pH Change	EC ($dS\ m^{-1}$)	SOM %	SOC %	SOC Mg C ha^{-1}
N1	0	67	28	82	0.21	6.97	3.83	-3.14	2.56	44.15	22.07	233
N1	1	59	20	83	0.20	7.00	3.35	-3.65	3.03	49.25	24.63	232
N1	5	57	19	82	0.15	7.53	4.77	-2.77	3.56	44.42	22.21	165
N1	15	65	19	84	0.18	7.15	4.65	-2.50	3.97	53.18	26.59	220
N2	0	53	21	69	0.32	6.33	2.95	-3.38	3.50	26.89	13.44	211
N2	1	47	17	70	0.29	6.23	2.57	-3.66	3.50	28.64	14.32	207
N2	5	52	15	70	0.21	6.56	4.18	-2.38	3.78	32.98	16.49	166
N2	15	57	20	78	0.22	7.06	4.87	-2.19	4.21	49.78	24.89	253
N3	0	58	24	69	0.31	6.53	2.75	-3.79	2.37	29.42	14.71	214
N3	1	57	22	72	0.25	6.59	2.81	-3.78	2.77	32.13	16.06	189
N3	5	64	25	78	0.19	6.78	3.40	-3.38	3.03	44.43	22.22	204
N3	15	63	26	78	0.19	6.16	3.44	-2.71	4.47	51.46	25.73	226
W1	0	21	10	50	0.56	6.90	3.16	-3.74	4.39	19.67	9.83	109
W1	1	29	11	55	0.48	6.74	3.34	-3.40	5.25	22.65	11.32	113
W1	5	26	12	58	0.50	6.72	3.12	-3.60	5.59	22.77	11.39	86
W1	15	22	10	52	0.57	6.83	4.22	-2.61	5.49	19.63	9.81	91
W2	0	19	9	58	0.46	6.82	3.44	-3.38	5.17	26.60	13.30	138
W2	1	24	11	64	0.41	6.37	3.07	-3.30	6.23	31.05	15.52	145
W2	5	30	13	63	0.39	7.04	3.75	-3.29	6.86	16.78	8.39	144
W2	15	24	7	72	0.30	7.04	4.46	-2.58	7.72	16.01	8.01	140
W3	0	25	12	59	0.47	6.48	3.59	-2.89	6.52	26.76	13.38	118
W3	1	28	12	62	0.45	6.61	3.58	-3.02	6.84	26.78	13.39	124
W3	5	44	16	64	0.40	6.82	4.05	-2.77	8.36	32.01	16.01	133
W3	15	37	13	65	0.39	6.80	3.46	-3.35	8.58	34.65	17.33	133

Table 2.8: Salt marsh warming experiment air and soil temperature results. Since temperature loggers were either installed or removed mid-month, the number of days the logger was active were reported. Temperature results in bold were determined by averaging the temperature measurements between treatments for each month. Numbers in parentheses represent standard deviation. N=8.

Year	Month	# Days Temperature was Measured	Air Temperature (˚C)			Soil Temperature (˚C)		
			Control	Warmed	# Days OTCs Increased Air Temp. >0.1 ˚C	Control	Warmed	# Days OTCs Increased Soil Temp. >0.1 ˚C
2012	July	16	**23.86** (0.20)	**24.17** (0.10)	10	**22.22** (0.40)	**21.54** (0.26)	0
	August	31	**24.66** (0.15)	**25.54** (0.48)	30	**22.78** (0.31)	**22.08** (0.06)	0
	September	30	**20.16** (0.37)	**20.91** (0.89)	29	**19.06** (0.34)	**18.56** (0.19)	0
	October	31	**14.88** (0.21)	**16.61** (1.55)	31	**14.57** (0.32)	**14.31** (0.19)	0
2013	June	17	**23.88** (0.39)	**23.80** (1.06)	9	**21.07** (0.13)	**20.14** (0.37)	0
	July	31	**27.39** (0.42)	**27.34** (0.87)	12	**24.30** (0.21)	**23.70** (0.44)	3
	August	31	**23.50** (0.63)	**24.20** (0.62)	25	**20.79** (0.22)	**20.88** (0.34)	16
	September	30	**19.06** (1.02)	**20.65** (0.46)	29	**17.84** (0.16)	**18.24** (0.28)	29
	October	11	**17.59** (0.85)	**18.71** (0.37)	9	**16.43** (0.16)	**16.96** (0.27)	11

Table 2.9: Summary and t-test results on aboveground biomass measurements taken at plots used for salt marsh soil warming experiment. * Indicates a signification difference was detected from t-test. Numbers in parentheses represents standard deviation.

Treatment	**Total Biomass** (g/m^2)			**Live Biomass** (g/m^2)			**Dead Biomass** (g/m^2)			**Stem density** ($\#/m^2$)	**Stem Length** (cm)
	Aug-12	May-12	Aug-13	Aug-12	May-12	Aug-13	Aug-12	May-12	Aug-13	Aug-13	Aug-13
Control	**1092.75**	**803.80**	**759.04**	**977.75**	**52.39**	**659.03**	**115.00**	**751.41**	**100.01**	**8900**	**25.96**
	(262.83)	(107.70)	(144.97)	(265.35)	(12.61)	(152.61)	(44.06)	(118.67)	(27.40)	(23.31)	(0.71)
Warmed	**1453.25**	**804.21**	**1449.00**	**1270.28**	**59.05**	**1045.26**	**182.97**	**745.16**	**403.74**	**11425**	**36.17**
	(173.34)	(93.67)	(293.75)	(151.29)	(10.76)	(70.95)	(30.07)	(95.29)	(327.90)	(22.02)	(3.24)
Difference	360.50	0.41	689.96	292.53	6.66	386.23	67.98	-6.24	303.73	2525.00	10.22
p-value	0.06	0.99	0.01*	0.10	0.45	0.01*	0.04*	0.94	0.11	0.17	0.03*

Table 2.10: Summary and t-test results on belowground biomass measurements taken from plots used for salt marsh soil warming experiment. No significant differences were detected between warmed and control belowground biomass in both the preseason (May) or peak season (August) measurements.

Treatment	**Coarse Roots** (g/m^2)		**Fine Roots** (g/m^2)		**Total Roots** (g/m^2)	
	May-13	Aug-13	May-13	Aug-13	May-13	Aug-13
Control	**197.30**	**583.09**	**411.73**	**853.05**	**609.03**	**1436.15**
	(40.04)	(65.93)	(37.50)	(200.91)	(50.58)	(239.60)
Warmed	**187.18**	**717.39**	**403.39**	**832.68**	**590.57**	**1550.08**
	(43.70)	(187.63)	(51.07)	(256.38)	(70.77)	(208.62)
Difference	-10.12	134.30	-8.34	-20.37	-18.46	113.93
p-value	0.74	0.23	0.8	0.91	0.67	0.5

FIGURES

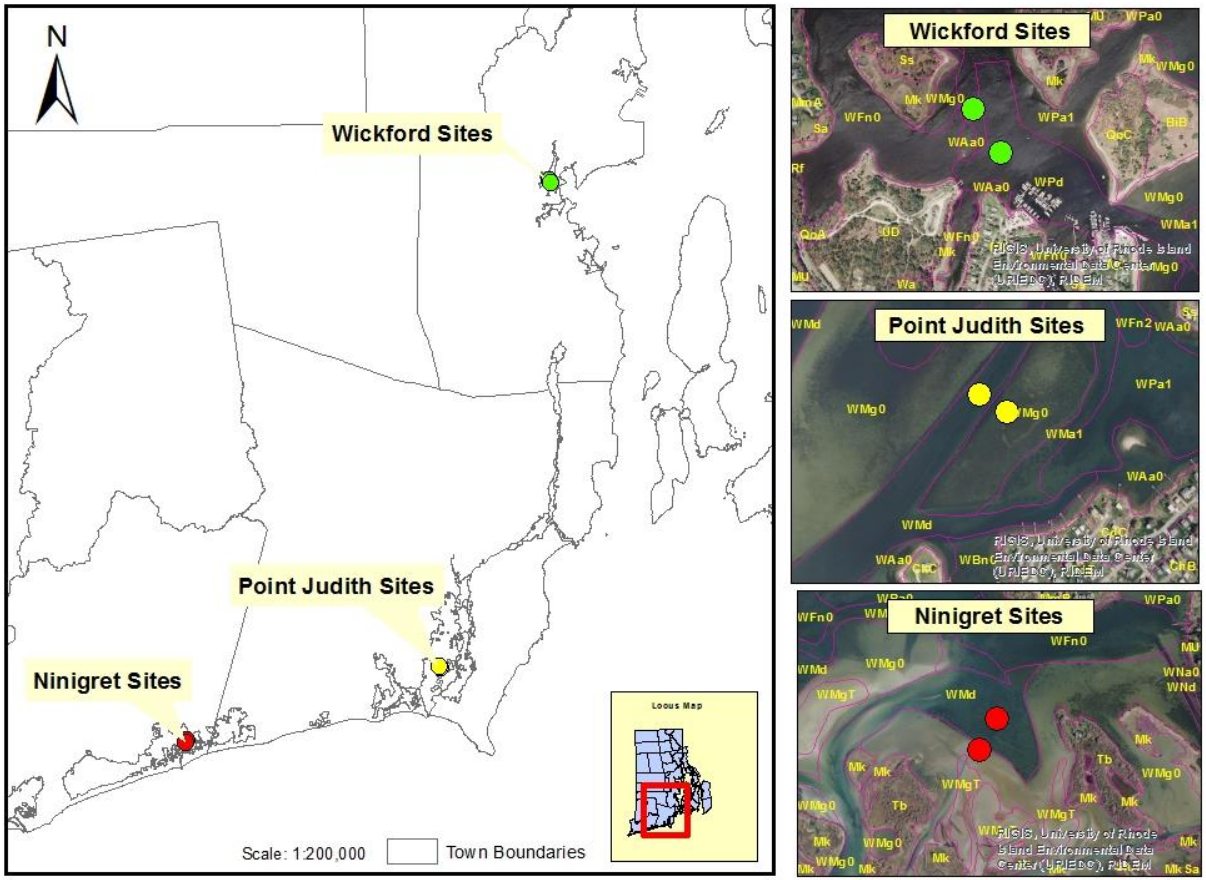


Figure 2.1: Locations of subaqueous sites used for ecological site determination and dredging comparison.

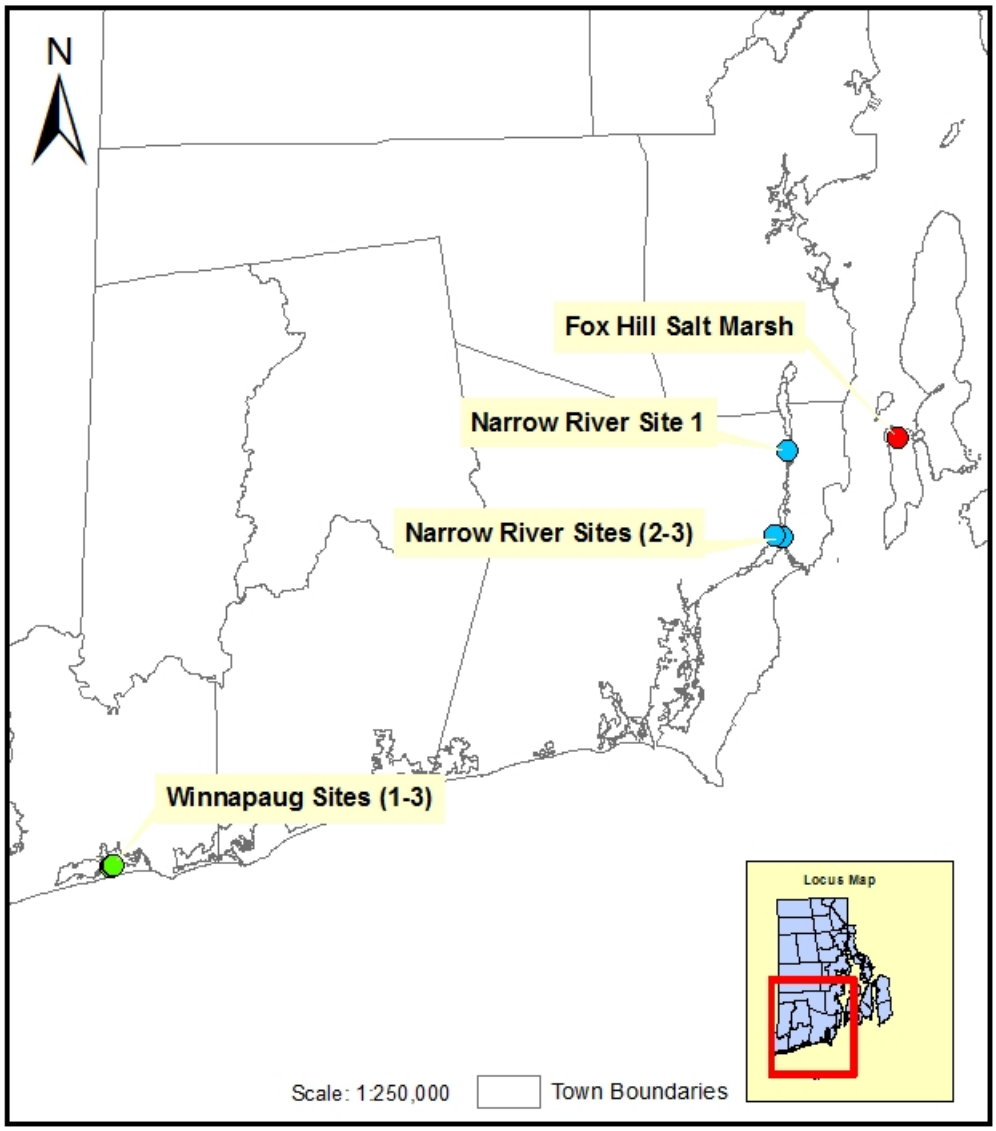


Figure 2.2: Locations of salt marsh sites. The Narrow River (Ipswich) and Winnapaug (Matunuck) soils were used for the study on the effects of ditching. The site at Fox Hill Salt Marsh was used for the warming experiment and correlated to the Ipswich soil series.

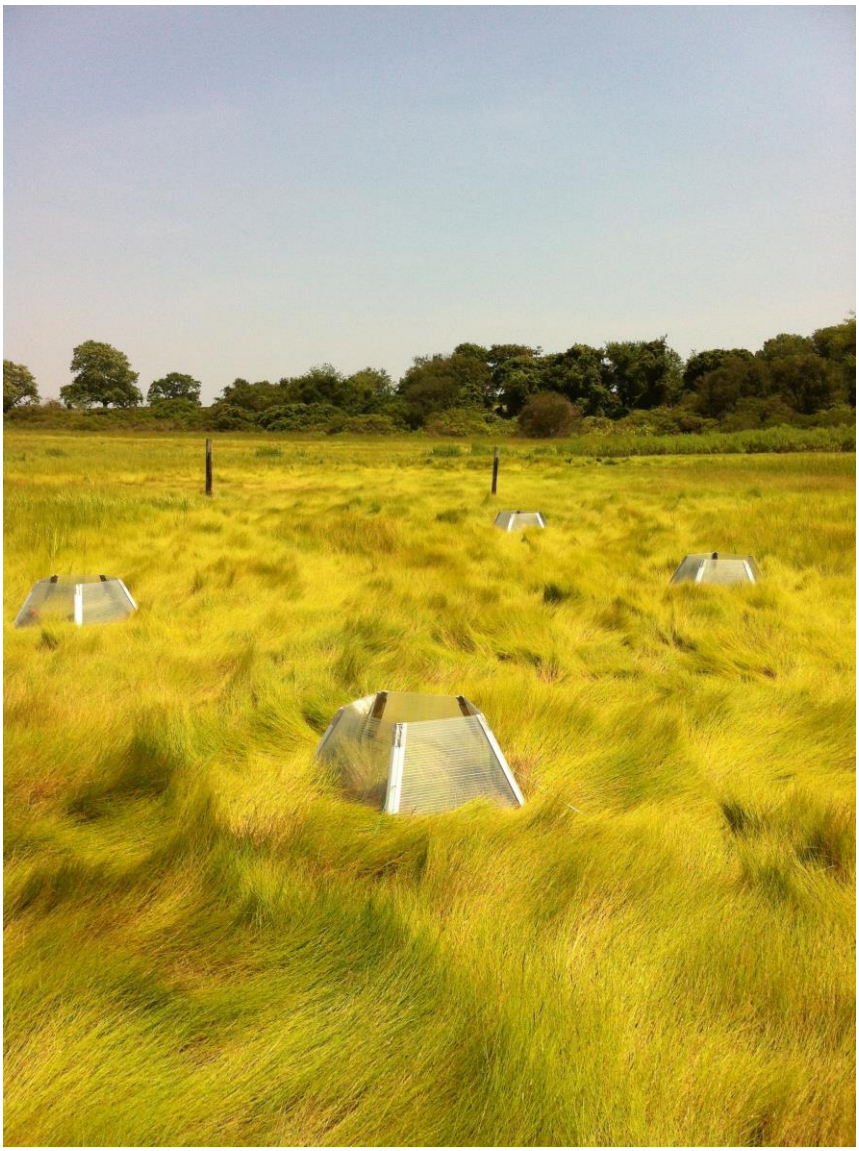


Figure 2.3: Open topped warming chambers (OTCs) at Fox Hill Salt Marsh used to simulate soil temperature increases. Design adapted from a study by Gedan and Bertness (2009).

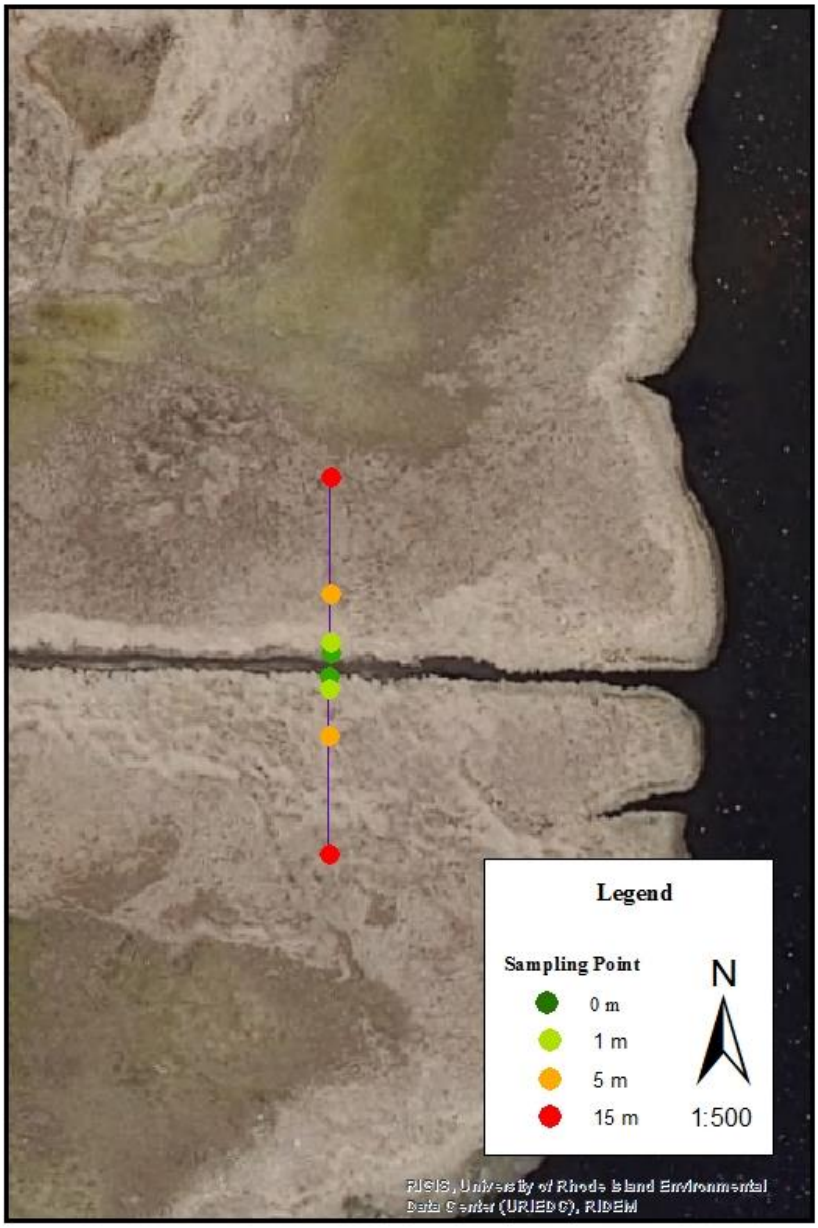


Figure 2.4: Sampling design used to for salt marsh ditching comparative study. Transects were delineated on either side on the ditch. The different colored represent sampling points that were measured from the ditch margin.

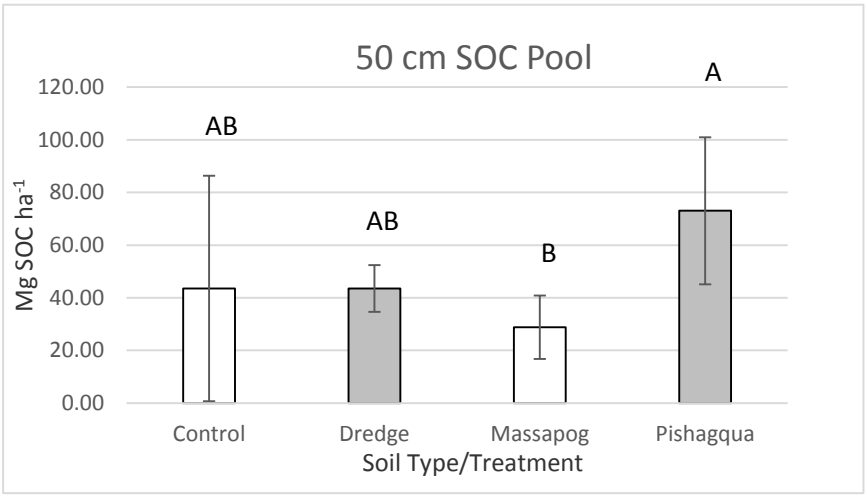
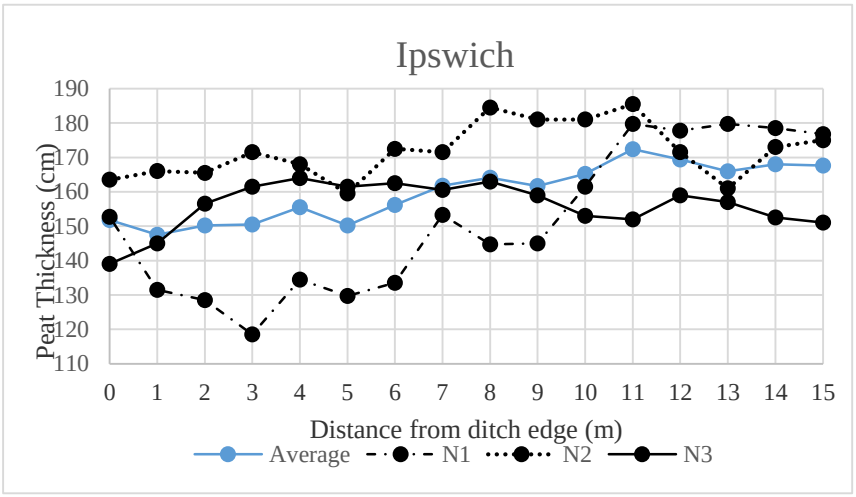


Figure 2.5: Subaqueous soil organic carbon (SOC) pools determined for the upper 50 cm of each soil type and between dredged and control sites. Letters signify differences between soils and treatments.



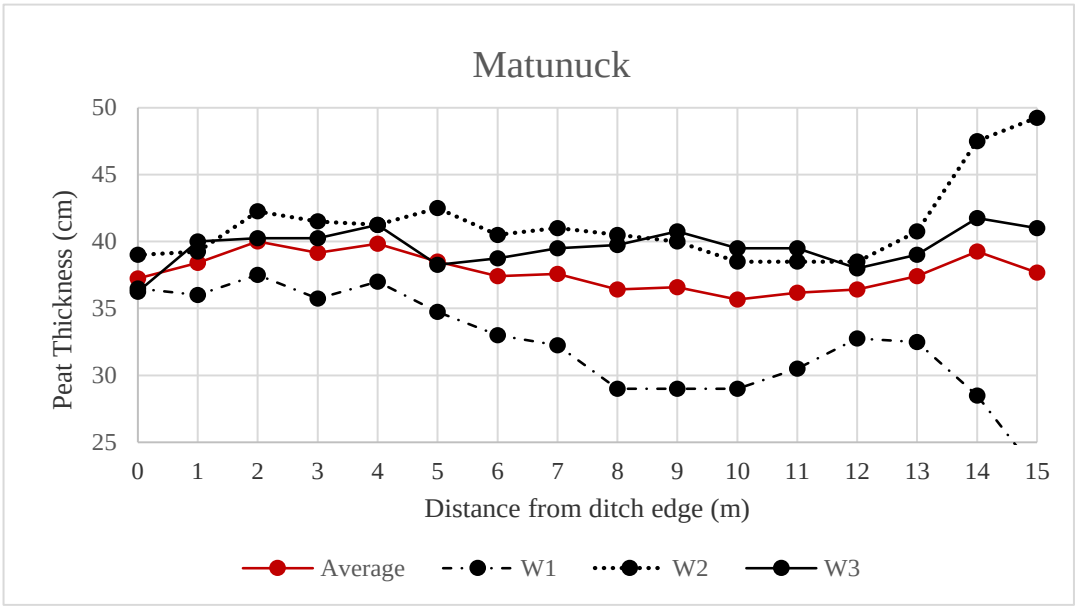


Figure 2.6: Peat thickness measurements along salt marsh ditch transects for Ipswich and Matunuck sites.

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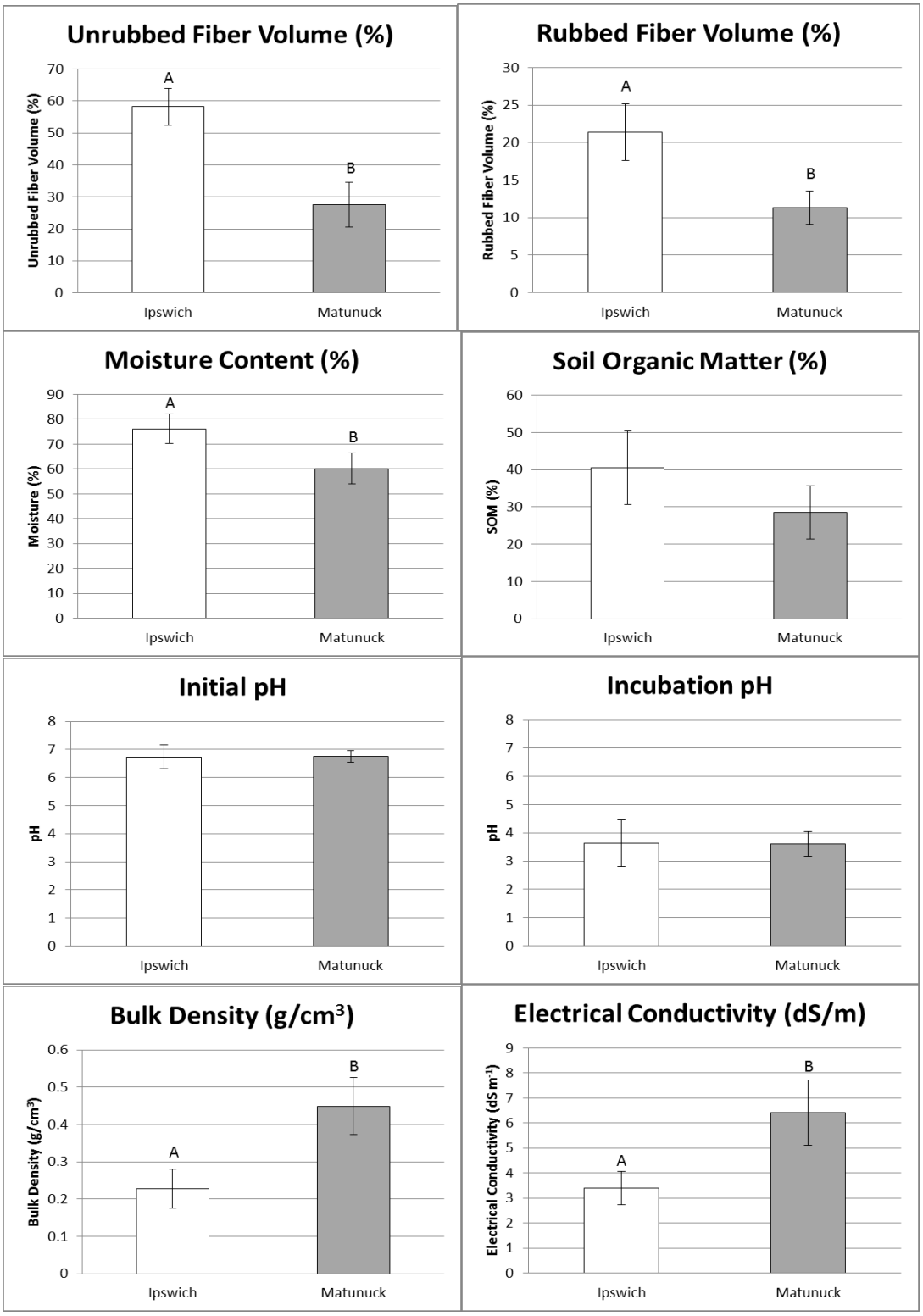

Figure 2.7: Soil properties averages for soils used in ditching study. Horizon values were weighted by thickness and used to determine the average for the upper 50 cm of the soil. Letters represent differences between Ipswich and Matunuck soils

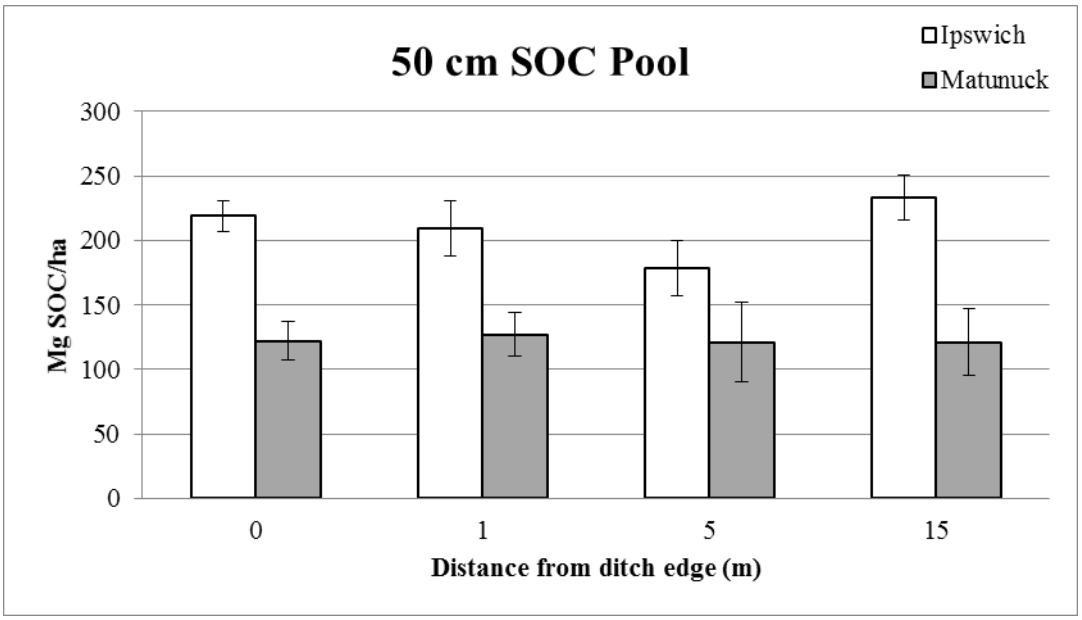

Figure 2.8: Salt marsh soil organic carbon pools (50 cm) for the Ipswich and Matunuck soils shown by sampling location along ditch transects. SOC averaged 210 Mg SOC/ha for the Ipswich soils and 123 Mg SOC/ha for Matunuck soils observed in this study.

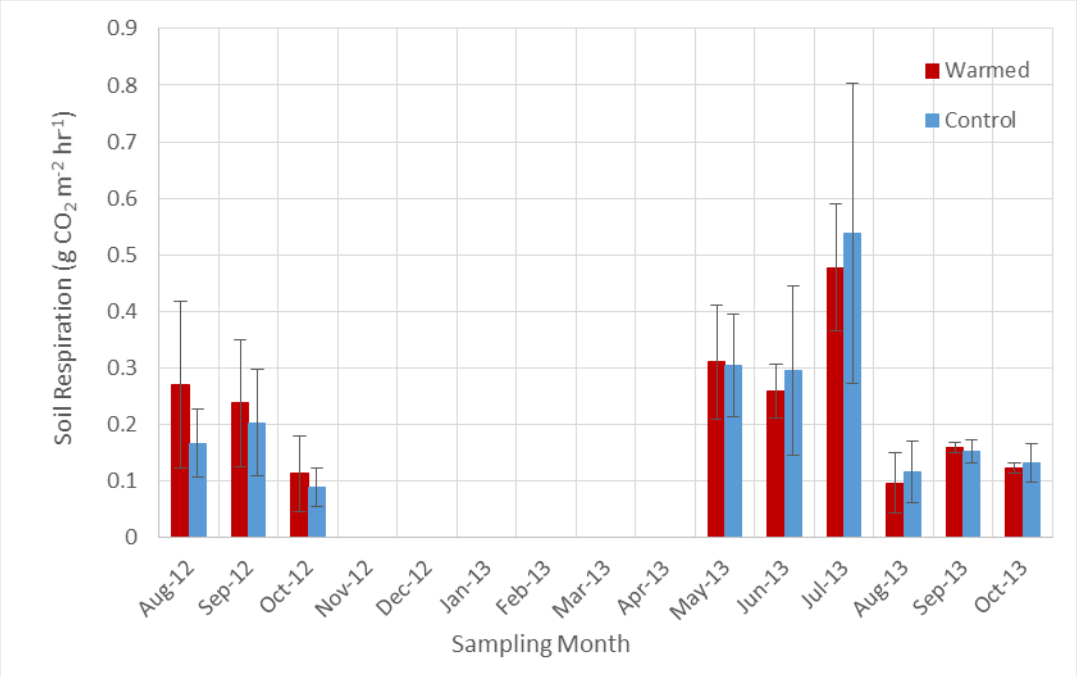

Figure 2.9: Average monthly soil respiration averages from salt marsh experimental warming plots and paired controls. No measurements were taken in November 2012 through April 2013. Error bars represent standard deviation.

APPENDIX 1: Upland and riparian soil descriptions and pedon laboratory data

Site: **BPP** Soil/Cover: Enfield, Coniferous Latitude: 41.47923

Classification: Coarse-silty over sandy, mixed, active, mesic Typic Dystrudepts Longitude: -71.56360

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oe	0-3	AS	7.5YR	2.5	1	MPM	-	-	-	-	CVFT
A	3-4	AW	2.5Y	2.5	1	SIL	-	-	1fGR	FR	CVFT, MFT
Ap	4-26	AS	10YR	4	2	SIL	-	-	1mSBK	FR	MFT, FMT
Bw1	26-42	CS	10YR	5	4	SIL	-	-	1mSBK	FR	FMT, FCT
Bw2	42-68	CS	10YR	5	3	SIL	-	-	1mSBK	FR	FCT
Bw3	68-85	CS	2.5Y	5	4	SIL	-	-	1mSBK	FR	-
2C	85+	-	2.5Y	6	4	S	GR	15	0SG	L	-

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oe	-	-	-	-	-	-	-	-	0	MPM	0.10
A	1	4	4	5	9	21	75	5	10	SIL	0.59
Ap	2	4	6	4	7	23	72	6	6	SIL	0.77
Bw1	1	3	8	8	11	28	66	6	2	SIL	0.80
Bw2	0	1	4	6	11	23	71	7	2	SIL	0.97
Bw3	-	-	-	-	-	-	-	-	-	-	-
2C	-	-	-	-	-	-	-	-	-	-	-

BPP Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oe	65.38	86.55	43.73	1.98	1.45	30.16	96	32	4.23	-
A	47.22	32.34	18.79	1.72	0.53	35.45	-	-	3.65	-
Ap	25.41	14.78	4.82	3.07	0.17	28.35	-	-	3.91	-
Bw1	26.99	4.71	1.61	2.92	0.07	23.00	-	-	4.33	-
Bw2	24.74	2.64	0.73	3.61	0.05	14.60	-	-	4.38	-
Bw3	-	-	-	-	-	-	-	-	-	-
2C	-	-	-	-	-	-	-	-	-	-

Site: **PHR** Soil/Cover: Enfield, Coniferous Latitude: 41.46735

Classification: Coarse-silty over sandy, mixed, active, mesic Typic Dystrudepts Longitude: -71.68704

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oi	0-1	AS	5YR	2.5	1	SPM	-	-	-	-	CVFT
A	1-3	CS	10YR	3	1	SIL	-	-	1mGR	FR	MVFT, MFT
Ap	3-25	AS	10YR	4	2	SIL	-	-	1mSBK	FR	MFT
Bw1	25-48	CS	10YR	5	3	SIL	-	-	1mSBK	FR	MFT, FMT, FCT
Bw2	48-65	CS	2.5Y	5	2	SIL	-	-	1mSBK	FR	FMT, FCT
Bw3	65-90	CS	10YR	5	4	SIL	-	-	1mSBK	FR	-
2C	90+	-	2.5Y	5	4	S	-	-	0SG	L	-

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oi	-	-	-	-	-	-	-	-	0	SPM	0.10
A	1	3	6	7	14	32	56	12	10	SIL	0.73
Ap	1	3	5	6	16	32	59	9	6	SIL	0.85
Bw1	1	1	3	4	18	28	68	4	2	SIL	1.14
Bw2	0	1	3	3	17	24	74	2	2	SIL	1.21
Bw3	-	-	-	-	-	-	-	-	-	-	-
2C	-	-	-	-	-	-	-	-	-	-	-

PHR Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oi	11.48	74.01	28.98	2.55	1.47	19.71	98	60	3.91	-
A	4.23	14.87	7.46	1.99	0.49	15.22	-	-	4.18	-
Ap	3.39	6.95	3.37	2.06	0.22	15.32	-	-	4.15	-
Bw1	1.86	3.06	0.70	4.37	0.07	10.00	-	-	4.21	-
Bw2	0.01	2.27	0.43	5.28	0.05	8.60	-	-	4.25	-
Bw3	-	-	-	-	-	-	-	-	-	-
2C	-	-	-	-	-	-	-	-	-	-

Site: **YWC** Soil/Cover: Bridgehampton, Coniferous Latitude: 41.50915

Classification: Coarse-silty, mixed, active, mesic Typic Dystrudepts Longitude: -71.56874

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oe	0-4	AS	7.5YR	2.5	1	MPM	-	-	-	-	CVFT
A	4-6	AS	10YR	2	1	SIL	-	-	1mGR	FR	CVFT
Ap	6-23	AS	10YR	4	2	SIL	-	-	1mSBK	FR	MVFT, MFT, FMT
Bw1	23-42	CS	10YR	5	4	SIL	-	-	1mSBK	FR	CMT
Bw2	42-61	CS	2.5Y	5	3	SIL	-	-	1mSBK	FR	FMT
Bw3	61-101	GS	5Y	5	2	SIL	-	-	1mSBK	FR	-
Bw4	101-127	CS	7.5YR	5	8	SIL	-	-	1mSBK	FR	-
2C1	127-152	CS	10YR	5	4	S	GR	15	0SG	L	-
2C2	152+	-	2.5Y	5	3	S	-	-	0SG	L	-

YWC Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs	(%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oe	-	-	-	-	-	-	-	-	0	MPM	0.10	
A	2	4	4	4	13	28	68	3	0	SIL	0.25	
Ap	2	3	5	5	16	30	65	5	3	SIL	0.82	
Bw1	0	7	2	2	16	21	73	6	0	SIL	1.08	
Bw2	0	7	1	2	16	19	74	6	0	SIL	1.07	
Bw3	-	-	-	-	-	-	-	-	-	-	-	
Bw4	-	-	-	-	-	-	-	-	-	-	-	
2C1	-	-	-	-	-	-	-	-	-	-	-	
2C2	-	-	-	-	-	-	-	-	-	-	-	

YWC Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oe	62.79	84.89	38.14	2.23	1.72	22.17	86	32	3.82	-
A	38.74	24.40	7.33	3.33	0.33	22.21	-	-	3.52	-
Ap	19.84	9.74	2.83	3.44	0.15	18.87	-	-	3.82	-
Bw1	20.42	5.14	0.57	9.01	0.04	14.25	-	-	4.1	-
Bw2	20.73	2.77	0.53	5.22	0.04	13.25	-	-	4.13	-
Bw3	-	-	-	-	-	-	-	-	-	-
Bw4	-	-	-	-	-	-	-	-	-	-
2C1	-	-	-	-	-	-	-	-	-	-
2C2	-	-	-	-	-	-	-	-	-	-

Site: **BPD** Soil/Cover: Enfield, Deciduous Latitude: 41.47768

Classification: Coarse-silty over sandy, mixed, active, mesic Typic Dystrudepts Longitude: -71.56192

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oe	0-3	CS	7.5YR	3	1	MPM	-	-	-	-	CVFT
A	3-5	AS	10YR	2	1	SIL	-	-	1fGR	VFR	CVFT, MFT,
Ap	5-24	AS	10YR	4	2	SIL	-	-	1mSBK	FR	MFT, CMT
Bw1	24-43	CS	10YR	5	4	SIL	-	-	1mSBK	FR	CFT, CMT
Bw2	43-80	CS	2.5Y	5	4	SIL	-	-	1mSBK	FR	FMT
2BC	80-87	CS	2.5Y	5	4	SIL	-	-	1mSBK	FR	-
2C	87+	-	2.5Y	5	4	S	GR	20	0SG	L	-

BPD Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oe	-	-	-	-	-	-	-	-	0	MPM	0.09
A	1	4	4	3	8	21	71	8	0	SIL	0.34
Ap	1	1	3	2	10	16	79	5	1	SIL	0.81
Bw1	1	1	2	1	8	13	79	8	0	SIL	1.01
Bw2	3	1	2	2	9	15	77	8	0	SIL	1.01
2BC	-	-	-	-	-	-	-	-	-	-	-
2C	-	-	-	-	-	-	-	-	-	-	-

BPD Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oe	55.97	82.60	41.92	1.97	1.91	21.95	72	28	4.28	-
A	39.66	27.46	12.53	2.19	0.53	23.64	-	-	4.37	-
Ap	18.56	5.98	3.17	1.89	0.17	18.65	-	-	3.89	-
Bw1	17.47	2.93	1.01	2.90	0.07	14.43	-	-	4.31	-
Bw2	17.78	2.64	0.59	4.48	0.05	11.80	-	-	4.1	-
2BC	-	-	-	-	-	-	-	-	-	-
2C	-	-	-	-	-	-	-	-	-	-

Site: **KPE** Soil/Cover: Enfield, Deciduous Latitude: 41.48715

Classification: Coarse-silty over sandy, mixed, active, mesic Typic Dystrudepts Longitude: -71.56949

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oe	0-3	CS	7.5YR	2.5	1	MPM	-	-	-	-	MVFT, MFT
A	3-6	CS	7.5YR	2.5	2	SIL	-	-	1fGR	FR	MFT, FMT
Ap	6-29	AS	10YR	4	2	SIL	-	-	1mSBK	FR	MFT, FMT, FCT
Bw1	29-38	CS	10YR	5	4	SIL	-	-	1mSBK	FR	FFT, FMT, FCT
Bw2	38-51	CS	2.5Y	5	4	SIL	-	-	1mSBK	FR	FMT
Bw3	51-73	GC	2.5Y	5	3	SIL	-	-	1mSBK	FR	-
2BC	73-95	CS	10YR	5	4	LS	-	10	1mSBK	FR	-
2C	95+	-	2.5Y	5	3	S	GR	17	0SG	L	-

KPE Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oe	-	-	-	-	-	-	-	-	0	MPM	0.12
A	2	4	6	5	7	26	68	7	2	SIL	0.35
Ap	3	5	7	5	9	29	67	4	8	SIL	0.76
Bw1	1	2	4	5	15	27	69	4	3	SIL	0.98
Bw2	0	2	4	5	17	29	65	6	1	SIL	1.04
Bw3	-	-	-	-	-	-	-	-	-	-	-
2BC	-	-	-	-	-	-	-	-	-	-	-
2C	-	-	-	-	-	-	-	-	-	-	-

KPE Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oe	64.30	76.95	39.02	1.97	2.12	18.41	72	24	4.22	-
A	35.23	18.20	10.21	1.78	0.56	18.23	-	-	4.22	-
Ap	23.13	8.06	4.17	1.93	0.24	17.38	-	-	3.79	-
Bw1	21.78	3.34	1.04	3.21	0.08	13.00	-	-	4.22	
Bw2	21.73	2.45	0.72	3.41	0.05	14.40	-	-	4.55	
Bw3	-	-	-	-	-	-	-	-	-	-
2BC	-	-	-	-	-	-	-	-	-	-
2C	-	-	-	-	-	-	-	-	-	-

Site: **LAR** Soil/Cover: Enfield, Deciduous Latitude: 41.46585

Classification: Coarse-silty over sandy, mixed, active, mesic Typic Dystrudepts Longitude: -71.55654

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oe	0-3	CS	5YR	2.5	1	MPM	-	-	-	-	CVFT
AE	3-4	CS	10YR	2	1	SIL	-	-	1fGR	VFR	MVFT, MFT, FMT
Ap	4-17	AS	10YR	4	2	SIL	-	-	1mSBK	FR	MFT
Bw1	17-37	CS	10YR	5	4	SIL	-	-	1mSBK	FR	CFT, CMT
Bw2	37-75	CS	10YR	5	3	SIL	-	-	1mSBK	FR	FMT
2CB	75-97	CS	10YR	4	3	LCoS	-	5	1fSBK	vFR	-
2C	97+	-	2.5Y	4	3	CoS	-	10	0SG	L	-

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oe	-	-	-	-	-	-	-	-	0	HPM	0.11
AE	-	-	-	-	-	-	-	-	-	-	-
Ap	3	6	9	7	13	38	54	8	2	SIL	0.88
Bw1	2	5	7	5	19	38	53	9	1	SIL	1.11
Bw2	2	5	7	5	13	33	59	8	1	SIL	1.16
2CB	-	-	-	-	-	-	-	-	-	-	-
2C	-	-	-	-	-	-	-	-	-	-	-

LAR Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oe	52.72	77.78	37.27	2.09	1.80	20.71	68	12	3.57	-
AE	-	-	-	-	-	-	-	-	-	-
Ap	16.00	6.70	3.20	2.09	0.21	15.24	-	-	4.35	-
Bw1	11.04	2.90	1.54	1.88	0.10	15.40	-	-	4.23	-
Bw2	13.43	2.26	0.53	4.27	0.12	4.42	-	-	4.38	-
2CB	-	-	-	-	-	-	-	-	-	-
2C	-	-	-	-	-	-	-	-	-	-

*AE horizon (3-4 cm) too thin to sample.

Site: **BZM** Soil/Cover: Merrimac, Coniferous Latitude: 41.54451

Classification: Sandy, mixed, active, mesic Typic Dystrudepts Longitude: -71.71733

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oi	0-5	AS	7.5YR	2.5	1	SPM	-	-	-	-	CVFT, MFT
Ap	5-16	AS	10YR	4	3	SL	-	1	1mSBK	FR	MFT
Bw1	16-31	CS	10YR	5	4	SL	-	1	1mSBK	FR	MFT
Bw2	31-50	CS	2.5Y	5	3	SL	-	2	1mSBK	FR	MFT, FMT
BC	50-70	CS	2.5Y	6	3	LCoS	-	10	1mSBK	VFR	CMT
C	70+	-	2.5Y	6	3	CoS	GRV	35	0SG	L	-

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oi	-	-	-	-	-	-	-	-	0	SPM	0.13
Ap	3	6	22	14	10	55	41	4	1	SL	0.98
Bw1	2	7	23	14	11	59	40	2	2	SL	1.11
Bw2	2	7	20	11	9	51	48	2	2	SL	1.20
Bw3	-	-	-	-	-	-	-	-	-	-	-
C	-	-	-	-	-	-	-	-	-	-	-

BZM Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oi	54.19	87.86	40.69	2.16	1.49	27.31	96	40	3.15	-
Ap	13.34	4.01	2.02	1.98	0.11	18.36	-	-	4.2	-
Bw1	12.51	2.88	0.83	3.47	0.06	13.83	-	-	4.07	-
Bw2	14.23	2.21	0.46	4.80	0.03	15.33	-	-	4.2	-
Bw3		-	-	-	-	-	-	-	-	-
C		-	-	-	-	-	-	-	-	-

Site: **FPC** Soil/Cover: Merrimac, Coniferous Latitude: 41.63261

Classification: Sandy, mixed, active, mesic Typic Dystrudepts Longitude: -71.64057

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oe	0-4	AS	5YR	3	1	MPM	-	NA	-	-	MVFT
A	4-7	AS	10YR	2	1	FSL	-	2	1fGR	FR	MVFT
Ap	7-15	AS	10YR	3	2	FSL	-	3	1mSBK	FR	MVFT, MFT
Bw1	15-38	CS	10YR	4	4	SL	-	10	1mSBK	FR	CFT, CMT
BC	38-54	CS	10YR	5	4	LfS	GR	25	1mSBK	VFR	FMT
C	54+	-	2.5Y	4	3	CoS	GR	30	0SG	L	-

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oe	-	-	-	-	-	-	-	-	0	MPM	0.10
A	2	5	8	11	10	37	60	3	0	SIL	0.52
Ap	4	8	13	15	15	55	43	2	3	FSL	0.86
Bw1	3	6	11	14	17	52	46	2	6	FSL	1.00
BC	5	6	10	15	18	54	45	2	20	FSL	1.00
C	-	-	-	-	-	-	-	-	-	-	-

FPC Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oe	50.09	69.85	36.41	1.92	1.84	19.79	88	24	3.23	-
A	33.83	35.40	17.25	2.05	0.85	20.29	-	-	3.46	-
Ap	30.34	7.05	4.32	1.63	0.24	18.00	-	-	3.96	-
Bw1	17.98	3.55	1.12	3.17	0.10	11.20	-	-	3.86	-
BC	13.20	2.29	0.80	2.86	0.06	13.33	-	-	4.1	-
C	-	-	-	-	-	-	-	-	-	-

Site: **PTC** Soil/Cover: Merrimac, Coniferous Latitude: 41.47163
Classification: Sandy, mixed, active, mesic Typic Dystrudepts Longitude: -71.66557

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oe	0-3	AS	10YR	2	1	MPM	-	-	-	-	MVFT, MFT
A	3-5	CS	10YR	2	1	FSL	-	1	1fGR	FR	MVFT, FFT
Ap	5-28	AS	10YR	4	2	SL	-	5	1mSBK	FR	CVFT, CFT
Bw1	28-46	AS	10YR	4	2	SL	-	10	1mSBK	FR	CFT
Bw2	46-68	CS	10YR	4	2	SL	-	12	1mSBK	FR	-
Bw3	68-85	CS	10YR	4	4	LS	GR	30	1mSBK	VFR	-
BC	85-105	GS	10YR	4	6	LS	GRV	35	1mSBK	VFR	-
C	105+	-	10YR	5	3	CoS	GRX	70	0SG	L	-

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oe	-	-	-	-	-	-	-	-	0	MPM	0.10
A	5	13	20	12	6	57	40	4	2	SL	0.80
Ap	5	12	22	16	7	63	36	2	5	SL	1.05
Bw1	14	15	20	12	5	66	32	2	22	SL	1.00
Bw2	17	20	13	10	8	69	30	1	9	SL	1.21
Bw3	-	-	-	-	-	-	-	-	-	-	-
BC	-	-	-	-	-	-	-	-	-	-	-
C	-	-	-	-	-	-	-	-	-	-	-

PTC Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oe	58.48	61.35	31.54	1.95	1.52	20.75	88	24	3.49	-
A	29.54	19.17	12.20	1.57	0.73	16.71	-	-	3.47	-
Ap	12.94	5.61	4.32	1.30	0.27	16.00	-	-	3.83	-
Bw1	7.26	2.08	1.05	1.98	0.09	11.67	-	-	3.81	-
Bw2	8.14	1.84	0.55	3.35	0.05	11.00	-	-	3.82	-
Bw3	-	-	-	-	-	-	-	-	-	-
BC	-	-	-	-	-	-	-	-	-	-
C	-	-	-	-	-	-	-	-	-	-

Site: **GST** Soil/Cover: Merrimac, Deciduous Latitude: 41.53793

Classification: Sandy, mixed, active, mesic Typic Dystrudepts Longitude: -71.44291

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oe	0-3	AS	5YR	2.5	1	MPM	-	0	-	-	MVFT, MFT
Ap	3-30	AS	10YR	4	1	FSL	-	2	1mSBK	FR	MVFT, MFT, FCT
Bw1	30-45	AS	2.5Y	4	2	SL	-	2	1mSBK	FR	MFT
Bw2	45-57	CS	2.5Y	5	3	SL	-	5	1mSBK	FR	CFT, FCT
BC	57-70	CS	2.5Y	5	3	GRLCoS	GR	16	1mSBK	VFR	-
C	70+	-	2.5Y	4	2	GRCoS	GR	20	0SG	L	-

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oe	-	-	-	-	-	-	-	-	0	HPM	0.15
Ap	2	6	11	15	21	56	42	2	0	FSL	1.23
Bw1	5	17	21	13	12	67	32	1	1	SL	1.23
Bw2	5	16	21	14	14	71	27	1	5	SL	1.23
BC	-	-	-	-	-	-	-	-	-	-	-
C	-	-	-	-	-	-	-	-	-	-	-

GST Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oe	53.43	73.84	34.12	2.1642229	1.39	18:1	60	12	3.32	-
Ap	10.73	3.35	1.46	2.2933995	0.08	20:1	-	-	4	-
Bw1	9.77	2.28	0.89	2.5628755	0.05	19:1	-	-	3.87	-
Bw2	7.76	1.87	0.62	3.0089412	0.03	17:1	-	-	4.11	-
BC	-	-	-	-	-	-	-	-	-	-
C	-	-	-	-	-	-	-	-	-	-

Site: **HAM** Soil/Cover: Merrimac, Deciduous Latitude: 41.54460

Classification: Sandy-skeletal, mixed, active, mesic Typic Udorthents Longitude: -71.45247

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oe	0-3	AS	7.5YR	2.5	1	MPM	-	-	-	-	MVFT, MMT
A	3-5	AS	10YR	2	1	FSL	-	5	1fSBK	VFR	MVFT, FFT, FMT
Ap	5-18	AS	2.5Y	3	1	SL	-	10	1mSBK	FR	CFT
Bw1	18-37	CS	2.5Y	4	2	SL	-	10	1mSBK	FR	FMT
Bw2	37-58	CS	2.5Y	4	3	GRLCoS	GR	20	1mSBK	VFR	-
BC	58-108	GS	2.5Y	4	3	GRS	GR	30	0SG	VFR	-
C	108+	-	5Y	4	2	GRVS	GRV	50	0SG	L	-

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oe	-	-	-	-	-	-	-	-	0	SPM	0.17
A	3	15	17	10	10	57	41	2	3	SL	0.32
Ap	7	13	16	13	11	61	38	1	8	SL	0.85
Bw1	11	29	25	11	7	84	16	1	29	LCoS	1.08
Bw2	24	43	20	2	1	91	8	1	27	CoS	1.09
BC	-	-	-	-	-	-	-	-	-	-	-
C	-	-	-	-	-	-	-	-	-	-	-

HAM Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oe	69.22	88.10	43.43	2.03	2.37	18.32	80	18	3.35	-
A	51.16	26.90	14.48	1.86	0.73	19.84	-	-	3.46	-
Ap	26.81	9.45	6.09	1.55	0.32	19.03	-	-	3.78	-
Bw1	8.21	2.04	1.36	1.50	0.08	17.00	-	-	4.32	-
Bw2	6.62	1.93	1.22	1.59	0.07	17.43	-	-	4.23	-
BC		-	-	-	-	-	-	-	-	-
C		-	-	-	-	-	-	-	-	-

Site: **PEC** Soil/Cover: Merrimac, Deciduous Latitude: 41.47430

Classification: Coarse-loamy, mixed, active, mesic Typic Dystrudepts Longitude: -71.54435

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oe	0-4	AS	5YR	2.5	1	MPM	-	-	-	-	MVFT, MFT
Ap	4-19	AS	10YR	3	2	SL	-	1	1mSBK	FR	CFT, FMT
Bw1	19-34	CS	10YR	4	3	SL	-	1	1mSBK	FR	FFT, FMT
Bw2	34-70	CS	10YR	5	4	SL	-	1	1mSBK	FR	FFT
Bw3	70-98	CS	10YR	5	4	LS	-	1	1mSBK	VFR	-
Bw4	98-122	CW	10YR	5	4	LCoS	-	5	1mSBK	VFR	-
C	122+	-	2.5Y	4	2	CoS	-	10	0SG	L	-

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oe	-	-	-	-	-	-	-	-	0	SPM	0.11
Ap	2	11	18	10	8	50	47	3	1	SL	0.87
Bw1	7	13	19	9	5	55	43	2	2	SL	1.15
Bw2	7	21	24	9	5	67	31	2	2	CoSL	1.26
Bw3	-	-	-	-	-	-	-	-	-	-	-
Bw4	-	-	-	-	-	-	-	-	-	-	-
C	-	-	-	-	-	-	-	-	-	-	-

PEC Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oe	44.09	78.89	38.29	2.06	1.92	19.94	98	48	3.41	-
Ap	17.06	7.07	4.06	1.74	0.19	21.37	-	-	4.02	-
Bw1	10.89	2.56	0.83	3.09	0.07	11.86	-	-	4.33	-
Bw2	8.39	1.69	0.48	3.52	0.00	-	-	-	4.45	-
Bw3	-	-	-	-	-	-	-	-	-	-
Bw4	-	-	-	-	-	-	-	-	-	-
C	-	-	-	-	-	-	-	-	-	-

*Note: Small 0.5 cm A horizon, too small to sample, 10YR 2/1, fsl, 1mGR, vfr, many vf roots

Site: **YWH** Soil/Cover: Enfield, Selective Harvest Latitude: 41.50915

Classification: Coarse-silty over sandy, mixed, active, mesic Typic Dystrudepts Longitude: -71.56785

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oe	0-4	AS	7.5YR	2.5	1	MPM	-	-	-	-	MVFT, MFT
A	4-5	AS	7.5YR	2.5	1	SIL	-	-	1fGR	VFR	MVFT, MFT
Ap	5-22	AS	10YR	4	2	SIL	-	-	1mSBK	FR	FFT, CMT
Bw1	22-37	CS	10YR	5	3	SIL	-	-	1mSBK	FR	MCT
Bw2	37-58	GS	10YR	6	3	SIL	-	-	1mSBK	FR	FCT
Bw3	58-84	AW	2.5Y	6	2	SIL	-	-	1mSBK	FR	-
2C	84-102+	-	7.5YR	5	4	S	GR	25	0SG	L	-

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oe	-	-	-	-	-	-	-	-	0	MPM	0.09
A	-	-	-	-	-	-	-	-	-	-	-
Ap	1	2	4	4	18	28	63	9	2	SIL	0.99
Bw1	2	1	2	3	17	24	69	7	1	SIL	1.27
Bw2	1	2	2	2	14	21	75	4	1	SIL	1.22
Bw3	-	-	-	-	-	-	-	-	-	-	-
2C	-	-	-	-	-	-	-	-	-	-	-

YWH Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oe	51.05	87.66	41.47	2.11	1.94	21.38	80	24	4.33	-
A	-	-	-	-	-	-	-	-	-	-
Ap	15.80	6.51	3.05	2.13	0.18	16.94	-	-	3.92	-
Bw1	15.14	3.24	0.91	3.56	0.07	13.00	-	-	4.09	-
Bw2	14.80	2.33	0.58	4.02	0.06	9.67	-	-	4.17	-
Bw3	-	-	-	-	-	-	-	-	-	-
2C	-	-	-	-	-	-	-	-	-	-

*A horixon (3.5-5 cm) not sampled

Site: **FPH** Soil/Cover: Merrimac, Selective Harvest Latitude: 41.63256

Classification: Sandy, mixed, active, mesic Typic Dystrudepts Longitude: -71.64106

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oe	0-4	AS	5YR	2.5	2	MPM	-	-	-	-	CVFT
A	4-7	CS	10YR	2	1	FSL	-	1	1fGR	VFR	MFT, MVFT
Ap	7-18	AS	10YR	3	2	FSL	-	2	1mSBK	FR	MFT, MVFT
Bw1	18-43	CS	10YR	4	4	SL	-	3	1mSBK	FR	CFT, CMT
Bw2	43-54	CS	10YR	5	4	SL	-	5	1mSBK	FR	FFT, CMT, FCT
BC	54-69	CS	10YR	5	4	LS	GR	17	1mSBK	VFR	-
C	69+	-	2.5Y	4	3	CoS	GRV	37	0SG	L	-

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oe	-	-	-	-	-	-	-	-	0	MPM	0.12
A	2	5	10	13	22	52	45	3	1	FSL	0.46
Ap	2	7	12	16	20	56	42	2	1	FSL	0.83
Bw1	3	8	11	14	18	54	45	1	1	FSL	0.98
Bw2	1	9	14	14	20	58	40	2	1	FSL	1.18
BC	-	-	-	-	-	-	-	-	-	-	-
C	-	-	-	-	-	-	-	-	-	-	-

FPH Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oe	58.11	89.91	41.83	2.15	1.78	23.50	88	32	4.48	-
A	31.38	22.00	9.97	2.21	0.48	20.77	-	-	4.2	-
Ap	24.64	8.57	4.56	1.88	0.26	17.54	-	-	3.82	-
Bw1	19.72	4.66	1.70	2.74	0.10	17.00	-	-	4.06	-
Bw2	17.90	2.17	0.50	4.35	0.04	12.50	-	-	4.11	-
BC	-	-	-	-	-	-	-	-	-	-
C	-	-	-	-	-	-	-	-	-	-

Site: **PTH** Soil/Cover: Merrimac, Selective Harvest Latitude: 41.84672

Classification: Sandy, mixed, active, mesic Typic Dystrudepts Longitude: -71.60177

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oe	0-3	AW	5YR	2.5	2	MPM	-	-	-	-	CVFT, MFT, FCT
Ap	3-17	AS	10YR	3	2	FSL	-	2	1mSBK	FR	FVFT,FFT
Bw1	17-31	CS	10YR	4	4	FSL	-	7	1mSBK	FR	FVFT, FFT
Bw2	31-57	CS	10YR	5	4	SL	GR	20	1mSBK	FR	FFT
BC	57+	-	2.5Y	4	3	LS	CB	28	0SG	L	-

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oe	-	-	-	-	-	-	-	-	0	MPM	0.11
Ap	4	9	10	14	13	51	45	4	1	FSL	0.90
Bw1	3	4	7	13	20	47	51	2	1	SIL	1.16
Bw2	5	5	8	15	21	55	44	2	1	FSL	1.08
BC	-	-	-	-	-	-	-	-	-	-	-

PTH Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oe	48.40	58.63	26.68	2.20	1.35	19.76	96	24	3.31	-
Ap	10.51	6.36	3.33	1.91	0.19	17.53	-	-	4	-
Bw1	6.98	2.90	0.97	2.99	0.07	13.86	-	-	4.41	-
Bw2	4.58	2.38	0.88	2.70	0.07	12.57	-	-	4.69	-
BC	-	-	-	-	-	-	-	-	-	-

Site: **BZW** Soil/Cover: Walpole, Red Maple Riparian Latitude: 41.54829

Classification: Sandy, mixed, mesic Cumulic Humaquepts Longitude: -71.71612

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oa	0-3	CS	10YR	2	1	MPT	-	-	-	-	MVFT, MFT, CCT
A	3-22	CS	10YR	2	2	SL	-	-	1mSBK	FR	MFT, MCT,
AC	22-41	AS	10YR	2	1	LS	GR	15	1fSBK	VFR	FFT
C	41+	-	10YR	3	1	S	GR	30	0SG	L	-

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oa	-	-	-	-	-	-	-	-	0	MUCK	0.13
A	1	2	3	6	9	22	71	7	0	MK SiL	0.40
AC	5	11	22	24	13	75	21	4	1	LS	1.18
C	18	28	23	15	5	90	10	0	52	CoS	0.86

BZW Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oa	75.76	84.70	40.64	2.08	1.62	25.09	64	12	5.07	-
A	61.06	22.82	11.84	1.93	0.77	15.38	-	-	3.74	-
AC	22.06	3.58	2.86	1.25	0.16	17.88	-	-	4.3	-
C	13.25	1.84	1.33	1.38	0.1	13.30	-	-	4.43	-

Notes: Common, faint depletions and many, prominent concentrations in AC horizon (22-41 cm). Few, faint concentrations and few faint depletions in C horizon 41+ cm.

Site: **GRW** Soil/Cover: Walpole, Red Maple Riparian Latitude: 41.54306

Classification: Sandy, mixed, mesic, Fluvaquentic Humaquepts Longitude: -71.68531

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oa	0-6	AS	10YR	2	1	MUCK	-	-	-	-	MVFT, CFT
A	6-23	CS	10YR	3	2	SL	-	5	1mSBK	FR	MFT, CMT, FCT
AC	23-58	CS	2.5Y	3	1	SL	-	10	1mSBK	FR	CVFT, CFT, FCT
C1	58-79	CW	10YR	4	1	CoS	-	15	0SG	L	FFT
C2	79+	-	10YR	4	1	CoS	GR	25	0SG	L	-

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oa	-	-	-	-	-	-	-	-	0	MUCK	0.11
A	5	9	13	11	15	53	43	4	0	FSL	0.86
AC	3	10	19	16	18	66	30	4	4	SL	1.06
C1	-	-	-	-	-	-	-	-	-	-	-
C2	-	-	-	-	-	-	-	-	-	-	-

GRW Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oa	69.88	89.51	42.74	2.09	2.26	18.91	28	12	3.67	-
A	49.71	7.57	3.96	1.91	0.26	15.23	-	-	4.48	-
AC	18.73	2.56	0.87	2.95	0.07	12.43	-	-	5.26	-
C1	-	-	-	-	-	-	-	-	-	-
C2	-	-	-	-	-	-	-	-	-	-

Notes:

Site: **KPW** Soil/Cover: Walpole, Red Maple Riparian Latitude: 41.48587

Classification: Sandy, mixed, mesic, Fluvaquentic Humaquepts Longitude: -71.56899

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
A	0-14	CS	10YR	2	1	MK SL	-	10	1mSBK	FR	MFT,CCT
BA	14-23	CS	5Y	4	1	LS	GR	20	1mSBK	FR	FFT, FCT
Bg	23-35	CS	2.5Y	4	2	LS	GR	20	1mSBK	FR	FFT
Cg1	35-55	CS	10YR	4	2	CoS	GR	30	0MA	VFR	-
Cg2	55-66	CS	2.5Y	5	2	CoS	GR	25	0SG	L	-
Cg3	66+	-	10YR	5	2	GrS	GRV	40	0SG	L	-

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
A	2	16	20	15	13	66	29	5	2	SL	0.69
BA	40	27	9	5	4	84	14	1	49	LCoS	0.68
Bg2	17	31	25	9	4	86	13	2	57	LCoS	0.70
Cg1	19	32	35	6	1	93	6	0	55	CoS	0.77
Cg2	-	-	-	-	-	-	-	-	-	-	-
Cg3	-	-	-	-	-	-	-	-	-	-	-

KPW Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
A	42.16	12.35	7.82	1.58	0.44	17.77	-	-	4.45	-
BA	7.16	1.45	0.71	2.04	0.03	23.67	-	-	5.07	-
Bg2	9.16	2.67	1.18	2.26	0.07	16.86	-	-	5.09	-
Cg1	8.94	1.77	0.80	2.22	0.03	26.67	-	-	5.12	-
Cg2	-	-	-	-	-	-	-	-	-	-
Cg3	-	-	-	-	-	-	-	-	-	-

Notes: Common, faint, coarse, Fe3+ masses in BA (14-23 cm). Common, faint, medium and fine, Fe3+ masses in Bg (23-35 cm). Few Distinct medium and fine Fe3+ masses in Cg1 (35-55 cm). Small Oe horizon < 1 cm thick.

Site: **HLS** Soil/Cover: Scarboro, Red Maple Riparian Latitude: 41.51134

Classification: Sandy-skeletal, mixed, mesic Histic Humaquepts Longitude: -71.64171

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oa1	0-4	CS	7.5YR	2.5	1	MUCK	-	-	-	-	MVFT, MFT
Oa2	4-21	CS	10YR	2	1	MUCK	-	-	-	-	MFT, MMT
A	21-47	AS	10YR	2	1	MK SL	-	-	0MA	FR	FFT
Cg	47+	-	2.5Y	4	1	S	GRV	40	0SG	L	-

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oa1	-	-	-	-	-	-	-	-	0	MUCK	0.21
Oa2	-	-	-	-	-	-	-	-	0	MUCK	0.38
A	-	-	-	-	-	-	-	-	1	MUCK	0.60
Cg	50	30	11	5	1	97	3	0	52	CoS	0.74

HLS Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oa1	53.02	42.76	25.55	1.67	0.66	38.71	40	10	4.01	3.75
Oa2	50.36	32.66	21.93	1.49	0.76	28.86	42	10	4.12	3.92
A	50.33	9.12	7.67	1.19	0.65	11.80	28	8	4.39	4.53
Cg	15.45	1.31	0.69	1.89	0.14	4.93	-	-	4.46	4.28

Site: **VRS** Soil/Cover: Scarboro, Red Maple Riparian Latitude: 41.53653

Classification: Sandy-skeletal, mixed, mesic Typic Humaquepts Longitude: -71.63963

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oe	0-2	CS	5YR	2.5	1	MPT	-	-	-	-	MVFT, MFT
Oa	2-12	CS	10YR	2	1	MUCK	-	-	-	-	CFT, FCT
A	12-32	AS	10YR	2	1	CoSL	-	5	0MA	FR	FFT
Cg	32+	-	10YR	7	2	CoS	GRX	65	0SG	L	VFVFT

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oe	-	-	-	-	-	-	-	-	0	MPT	0.13
Oa	-	-	-	-	-	-	-	-	0	MUCK	0.17
A	35	24	4	2	2	67	31	2	1	CoSL	0.66
Cg	73	22	2	1	0	99	1	0	95	CoS	0.82

VRS Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oe	69.73	57.57	26.86	2.14	1.60	16.79	76	28	4.05	3.16
Oa	79.02	58.32	28.50	2.05	1.75	16.29	64	12	4.08	3.3
A	46.17	6.54	3.19	2.05	0.32	9.97	-	-	4.21	3.62
Cg	15.57	0.97	0.48	2.02	0.12	4.00	-	-	4.81	3.99

Site: **BZS** Soil/Cover: Scarboro, Red Maple Riparian Latitude: 41.54897

Classification: Sandy, mixed, mesic Histic Humaquepts Longitude: -71.72007

Field Data

Horizon	Depth (cm)	Boundary	Color			Field texture	CF Modifier	CF Volume (%)	Structure	Moist Consistence	Roots
			Hue	Value	Chroma						
Oa1	0-5	AS	7.5YR	2.5	1	MUCK	-	-	-	-	FVFT, MFT
Oa2	5-20	CS	10YR	2	1	MUCK	-	-	-	-	MCT, CFT
Oa3	20-31	AS	10YR	2	1	MK SL	-	5	0MA	FR	FFT
Cg	31+	-	2.5Y	4	1	S	GR	25	0SG	L	-

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF Weight (%)	Lab texture	Bulk Density (g/cm^3)
Oa1	-	-	-	-	-	-	-	-	0	MUCK	0.09
Oa2	-	-	-	-	-	-	-	-	0	MUCK	0.33
Oa3	-	-	-	-	-	-	-	-	1	MUCK+	0.63
Cg	9	19	35	28	4	95	5	0	36	CoS	1.34

BZS Lab Data (continued)

Horizon	Moisture (%)	SOM (%)	Carbon (%)	SOM:SOC	Nitrogen (%)	C:N	Unrubbed fibers (%)	Rubbed fibers (%)	pH (1:1)	pH (2:1)
Oa1	80.64	86.18	42.66	2.02	1.60	26.66	64	16	4.54	3.57
Oa2	63.50	40.81	24.97	1.63	1.75	14.27	60	12	4.28	3.87
Oa3	44.09	17.06	14.53	1.17	0.32	45.41	32	12	4.75	4.37
Cg	14.86	0.15	0.1	1.48	0.12	0.83	-	-	5.09	4.96

Notes: Oa3 horizon (20-31 cm) originally called mineral (A) but meets requirements for organic materials, so horizonation was changed.

APPENDIX 2: Tree core data for upland and riparian sites taken at 4.5ft

Site	Species	DBH (in)	Height (ft)	Growth Rate (#/in)	DBH Age	Total Age	Site Index
BPP	*Pinus strobus*	21.0	65	15	49	61	54
BPP	*Pinus strobus*	14.8	63	10	46	58	55
BPP	*Pinus rigida*	15.9	58.5	19	56	62	55
BPP	*Pinus rigida*	15.4	55	15	52	58	53
PHR	*Pinus strobus*	23.6	62	10	54	66	49
PHR	*Pinus strobus*	22.8	65	11	56	68	50
PHR	*Pinus rigida*	17.0	60	14	70	76	55
PHR	*Acer rubrum*	14.8	57	13	56	60	50
YWC	*Pinus strobus*	12.6	60	12	55	67	47
YWC	*Pinus strobus*	13.5	62.5	22	78	90	40
YWC	*Pinus strobus*	12.6	60	14	53	65	48
YWC	*Pinus strobus*	17.7	62.5	7	48	60	53
YWC	*Quercus velutina*	17.6	67.5	18	89	92	54
YWC	*Quercus velutina*	17.3	67.5	13	72	75	55
BPD	*Quercus coccinea*	18.1	77.5	13	71	74	63
BPD	*Quercus coccinea*	17.3	62	14	81	84	50
BPD	*Quercus alba*	11.2	53	2.2	85	88	43
KPE	*Quercus alba*	23.3	65	14	88	91	52
KPE	*Quercus alba*	16.5	75	15	87	90	60
KPE	*Quercus alba*	24.6	68	17	103	106	54
LAR	*Quercus alba*	11.3	48	30	88	91	39
LAR	*Quercus alba*	12.0	55	18	59	62	46
LAR	*Quercus alba*	20.4	62.4	18	98	101	50
LAR	*Quercus coccinea*	11.6	55	15	67	70	45
LAR	*Acer rubrum*	13.6	57.5	18	91	95	38
BZM	*Pinus strobus*	17.8	68	12	54	66	53
BZM	*Pinus strobus*	14.4	68	15	39	51	67
BZM	*Pinus strobus*	17.1	64	13	44	56	58
BZM	*Pinus rigida*	8.4	37	19	50	56	36
BZM	*Pinus rigida*	13.9	71	19	54	60	67
BZM	*Pinus rigida*	11.1	68	14	29	35	79

APPENDIX 2 (continued): Tree core data

Site	Species	DBH (in)	Height (ft)	Growth Rate (#/in)	DBH Age	Total Age	Site Index
FPC	*Pinus strobus*	17.5	78	10	63	75	56
FPC	*Pinus strobus*	16.2	76	11	52	64	61
FPC	*Pinus strobus*	13.6	77.4	14	61	73	56
PTC	*Pinus strobus*	22.2	80	13	77	89	52
PTC	*Pinus strobus*	22.7	80	13	71	83	54
PTC	*Pinus strobus*	21.9	82	9	69	81	56
GST	*Quercus velutina*	9.8	50	19	58	61	42
GST	*Quercus velutina*	10.6	50	16	50	53	42
GST	*Quercus coccinea*	25.6	65	15	85	88	52
HAM	*Quercus velutina*	15.0	50	12	75	78	41
HAM	*Quercus velutina*	21.3	54	16	72	75	44
HAM	*Quercus alba*	9.8	55	16	44	47	48
PEC	*Quercus coccinea*	10.6	56	22	76	79	45
PEC	*Quercus coccinea*	16.2	63.5	18	94	97	51
PEC	*Quercus coccinea*	13.7	60	21	96	99	48
PEC	*Acer rubrum*	8.2	52.2	29	75	79	38
PEC	*Acer rubrum*	6.5	42.5	19	57	61	37
PEC	*Acer rubrum*	10.8	50	18	75	79	36
YWH	*Pinus strobus*	23.2	75	15	58	70	56
YWH	*Pinus strobus*	11.5	65	20	62	74	47
YWH	*Pinus strobus*	17.1	70	23	63	75	50
YWH	*Quercus velutina*	18.9	70	15	98	101	56
YWH	*Quercus velutina*	14.3	72.5	17	90	93	58
YWH	*Quercus velutina*	23.2	75	10	93	96	60
FPH	*Pinus strobus*	24.2	52	9	87	99	32
FPH	*Pinus strobus*	17.4	86	11	74	86	57
FPH	*Pinus strobus*	15.7	90	11	83	95	56
FPH	*Quercus coccinea*	11.2	72	13	79	82	58
FPH	*Quercus alba*	19.3	66	17	84	87	53
PTH	*Pinus strobus*	13.1	85	12	41	53	81
PTH	*Pinus strobus*	16.3	80	10	42	54	75
PTH	*Pinus strobus*	18.1	82	11	53	65	65

APPENDIX 2 (continued): Tree core data

Site	Species	DBH (in)	Height (ft)	Growth Rate (#/in)	DBH Age	Total Age	Site Index
BZW	*Acer rubrum*	7.0	45	14	33	37	57
BZW	*Acer rubrum*	13.8	45	14	57	61	39
BZW	*Acer rubrum*	11.1	68	14	29	33	93
BZW	*Pinus strobus*	17.3	65	10	45	57	58
BZW	*Pinus rigida*	9.4	65	12	45	51	64
GRW	*Acer rubrum*	17.3	61	12	68	72	47
GRW	*Acer rubrum*	10.2	58	10	66	70	46
GRW	*Acer rubrum*	11.3	54	11	61	65	45
KPW	*Acer rubrum*	9.3	48	16	55	59	42
KPW	*Acer rubrum*	13.5	62	21	80	84	44
KPW	*Acer rubrum*	15.4	52	16	77	81	37
HLS	*Acer rubrum*	11.3	64	21	72	76	48
HLS	*Acer rubrum*	8.0	48	33	72	76	36
HLS	*Acer rubrum*	10.0	58	22	73	77	43
VRS	*Acer rubrum*	8.5	55	15	53	57	50
VRS	*Acer rubrum*	12.4	62	14	43	47	65
VRS	*Acer rubrum*	17.3	61.5	15	66	70	49
BZS	*Acer rubrum*	9.5	54	13	58	62	46
BZS	*Acer rubrum*	10.3	52	16	58	62	44
BZS	*Acer rubrum*	8.6	52	19	44	48	53

APPENDIX 3: Riparian soil respiration measurements for treatment plots used in nitrogen enrichment study.

Site	Treatment	Soil Respiration Measurements by Month (g CO_2 m^{-2} hr^{-1})							
		May	**June**	**July**	**August**	**September**	**October**	**Mean**	**STDEV**
HLS	Control	0.33	0.24	0.25	0.41	0.55	0.19	**0.33**	0.13
	Low	0.17	0.12	0.36	0.43	0.50	0.17	**0.29**	0.16
	High	0.59	0.53	0.56	0.50	0.85	0.18	**0.53**	0.21
BZS	Control	0.18	0.36	0.32	0.17	0.63	0.16	**0.30**	0.18
	Low	0.23	0.26	0.40	0.33	0.49	0.15	**0.31**	0.12
	High	0.25	0.26	0.33	0.36	0.46	0.17	**0.31**	0.10
VRS	Control	0.23	0.11	0.30	0.22	0.27	0.17	**0.22**	0.07
	Low	0.18	0.09	0.21	0.27	0.26	0.17	**0.20**	0.07
	High	0.31	0.21	0.47	0.24	0.12	0.11	**0.24**	0.14
Mean		**0.28**	**0.24**	**0.36**	**0.33**	**0.46**	**0.17**		
STDEV		0.13	0.14	0.11	0.11	0.22	0.02		

APPENDIX 4: Subaqueous soil descriptions and pedon laboratory

Site: Ninigret Control (Massapog Series)

Field Data

Horizon	Depth (cm)	Color			Field texture	Coarse Frags (%)	Fluidity Class
		Hue	Value	Chroma			
Cg1	0-14	5Y	5	1	lfs	-	NF
Cg2	14-35	N	5	-	lfs	-	NF
Cg3	35-57	N	5	-	ls	-	NF
Ab	57-75	10Y	2.5	-	fsl	-	NF
Cse	75-107	10Y	5	-	fs	5% shells	NF
C'g	107-137	N	3	-	fs	-	NF
C'se	137-149	N	4	-	ls	-	NF
C"g	149-158	5Y	4	1	fsl	-	NF
C"se	158+	N	4	-	fsl	-	NF

Ninigret Control Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	sand (%)	silt (%)	clay (%)	CF (%)	Shells (%)	Lab texture	Bulk Density (g/cm^3)
Cg1	0	1	5	57	22	85	15	1	0	0	lfs	1.25
Cg2	0	1	6	56	32	94	5	1	0	0	fs	1.29
Cg3	0	4	22	46	24	95	4	1	0	0	s	1.06
Ab	0	1	5	33	36	76	23	1	0	0	lfs	1.30
Cse	0	1	11	60	22	94	6	0	0	0	fs	1.43
C'g	0	0	4	75	17	97	3	0	0	0	fs	1.42
C'se	0	0	1	51	43	94	5	0	0	0	fs	1.31
C"g	0	0	1	49	47	97	3	0	0	0	fs	1.33
C"se	0	0	2	29	64	95	4	1	0	0	fs	1.15

Lab Data (Continued)

Horizon	SOM (%)	SOC (%)	$CaCO_3$ (%)	EC 1:5 ($dS\ m^{-1}$)	Initial pH	Incubation pH (16 week)	pH change
Cg1	0.47	0.23	2.19	1.79	7.93	6.84	-1.09
Cg2	0.59	0.30	2.89	1.97	7.64	7.74	0.1
Cg3	0.35	0.17	2.09	0.95	8	8.23	0.23
Ab	1.78	0.89	6.26	3.26	7.77	3.05	-4.72
Cse	0.67	0.33	2.04	1.48	8.8	3.09	-5.71
C'g	0.59	0.29	4.55	2.14	8.02	5.11	-2.91
C'se	0.76	0.38	4.09	2.62	7.25	3.01	-4.24
C"g	0.64	0.32	6.13	2.84	7.8	8.35	0.55
C"se	1.41	0.71	7.64	2.86	7.45	2.84	-4.61

Site: Ninigret Dredge (Massapog Series)

Field Data

Horizon	Depth (cm)	Color			Field texture	Coarse Frags (%)	Fluidity Class	Notes
		Hue	Value	Chroma				
Ase	0-7	N	3	-	fsl	-	MF	Many eelgrass rhizomes
Cse1	7-22	N	4	-	ls	-	NF	Eelgrass ditris
Cse2	22-35	N	4	-	ls	15% shells	NF	-
Cse3	35-54	N	4	-	ls	-	NF	-
Aseb	54-66	10Y	3	-	lfs	-	NF	Two N 4/-, 2 cm, lfs lenses
C'se	66-79	5Y	4	1	ls	-	NF	-
Cg1	79-101	5Y	4	1	ls	5% shells	NF	-
Cg2	101-129	5Y	3.5	1	ls	45% shells	NF	Clam shells
C"se1	129-144	5Y	4	1	ls	-	NF	-
C"se2	144-152	10Y	4	-	fsl	-	NF	-
C"se3	152-165	5Y	3.5	1	ls	-	NF	-
C"se4	165+	10Y	4	-	fsl	-	NF	-

Ninigret Dredge Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	sand (%)	silt (%)	clay (%)	CF (%)	Shells (%)	Lab texture	Bulk Density (g/cm^3)
Ase	0	0	2	39	35	77	21	3	0	0	lfs	1.06
Cse1	0	3	11	55	16	85	13	1	0	0	lfs	1.31
Cse2	0	1	6	56	29	93	6	1	0	1	fs	1.13
Cse3	0	0	2	35	56	93	6	1	0	0	vfs	1.15
Aseb	0	0	0	32	58	90	8	1	0	0	vfs	1.02
C'se	0	0	2	40	51	93	6	1	0	0	vfs	1.15
Cg1	0	1	5	42	36	84	15	1	0	0	lfs	1.17
Cg2	0	1	8	55	31	95	4	1	0	5	fs	1.18
C"se1	0	0	1	31	62	94	5	1	0	0	vfs	1.17
C"se2	0	0	0	10	68	79	18	4	0	0	lvfs	0.96
C"se3	0	0	0	11	67	79	20	1	0	0	lvfs	1.07
C"se4	0	0	0	1	27	28	62	10	0	0	sil	0.99

Ninigret Dredge Lab Data (Continued)

Horizon	SOM (%)	SOC (%)	$CaCO_3$ (%)	EC 1:5 (dS m^{-1})	Initial pH	Incubation pH (16 week)	pH change
Ase	2.04	1.02	7.48	4.55	7.2	3.54	-3.66
Cse1	1.49	0.75	5.28	2.51	7.35	3.34	-4.01
Cse2	0.96	0.48	3.89	2.21	7.05	3.74	-3.31
Cse3	0.75	0.38	3.69	2.48	5.39	3.4	-1.99
Aseb	1.73	0.86	4.14	2.83	6	3.17	-2.83
C'se	1.14	0.57	3.47	2.1	6.33	3.17	-3.16
Cg1	1.07	0.53	5.64	2.28	7.37	5.31	-2.06
Cg2	0.67	0.34	3.95	2.36	7.79	7.28	-0.51
C"se1	0.68	0.34	3.49	2.2	7.68	3.55	-4.13
C"se2	1.49	0.74	6.23	3.05	7.61	3.3	-4.31
C"se3	0.70	0.35	3.52	1.88	7.54	3.51	-4.03
C"se4	4.22	2.11	14.25	3.91	7.64	3.51	-4.13

Site: Point Judith Control (Massapog Series)

Field Data

Horizon	Depth (cm)	Color			Field texture	Coarse Frags (%)	Fluidity Class	Notes
		Hue	Value	Chroma				
A	0-21	5Y	4	1	ls	-	NF	-
Cse1	21-45	10Y	4	-	ls	-	NF	-
Cse2	45-71	5GY	4	-	fs	-	NF	-
Cse3	71-84	N	5	-	fs	-	NF	-
Cg	84-104	N	4	-	ls	5% shells	NF	clam shells
Ab1	104-124	N	3	-	fsl	5% shells	NF	clam shells
Ab2	124-133	10Y	4	-	lfs	2% shells	NF	clam shells
C'g1	133-173	5GY	4	-	ls	-	NF	-
C'g2	173-178	5Y	3	1	fsl	-	NF	-
C'g3	178+	N	4	-	ls	-	NF	Slight sulfurous odor

Point Judith Control Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF (%)	Shells (%)	Lab texture	Bulk Density (g/cm^3)
A	0	0	7	61	23	91	7	2	0	0	fs	1.26
Cse1	0	0	6	80	11	97	2	1	0	0	fs	0.85
Cse2	0	0	2	72	22	96	4	1	0	0	fs	1.11
Cse3	0	0	4	61	29	94	5	1	0	0	fs	1.21
Cg	0	0	3	31	51	85	14	1	0	0	lvfs	1.28
Ab1	0	0	3	69	25	97	3	0	0	0	fs	1.40
Ab2	0	0	2	65	30	98	1	0	0	0	fs	1.45
C'g1	0	0	1	60	34	95	4	0	0	0	fs	1.41
C'g2	0	0	1	42	43	86	13	1	0	0	fs	1.14
C'g3	0	0	2	65	28	95	4	1	0	0	fs	1.52

Point Judith Control Lab Data (Continued)

Horizon	SOM (%)	SOC (%)	$CaCO_3$ (%)	EC 1:5 (dS m^{-1})	Initial pH	Incubation pH (16 week)	pH change
A	1.24	0.62	6.86	2	7.82	8.51	0.69
Cse1	0.48	0.24	2.05	0.84	7.93	3.46	-4.47
Cse2	0.62	0.31	2.30	1.09	8.06	3.21	-4.85
Cse3	0.90	0.45	3.74	1.53	8.28	2.93	-5.35
Cg	2.45	1.22	6.79	1.92	8.27	6.19	-2.08
Ab1	1.39	0.70	4.86	2.72	7.92	6.7	-1.22
Ab2	1.25	0.62	6.38	2.76	7.98	7.9	-0.08
C'g1	0.72	0.36	6.31	2.57	8.11	8.38	0.27
C'g2	2.40	1.20	11.66	3.48	7.91	7.89	-0.02
C'g3	0.79	0.39	5.40	2.74	7.98	8.33	0.35

Site: Point Judith Dredge (Massapog Series)

Field Data

Horizon	Depth (cm)	Color			Field texture	Coarse Frags (%)	Fluidity Class	Notes
		Hue	Value	Chroma				
A	0-6	N	2.5	-	mk ls	-	MF	Color change with 3% hydrogen peroxide
Cg1	6-27	N	3	1	lfs	-	NF	Color change with 3% hydrogen peroxide
Cg2	27-49	N	4	-	ls	-	NF	Color change with 3% hydrogen peroxide
Cg3	49-58	N	4	-	ls	30% shells	NF	Color change with 3% hydrogen peroxide; Shells
Cg4	58-65	10Y	3	-	sl	-	NF	Color change with 3% hydrogen peroxide
Aseb	65-74	2.5Y	3	1	fsl	-	NF	-
Cse	74-114	10Y	3	-	fsl	-	NF	-
C'g1	114-146	5Y	4	1	fsl	-	NF	Slight sulfurous odor
C'g2	146-165	N	4	1	lfs	-	NF	Slight sulfurous odor
C'se1	165-172	10Y	3	-	fsl	-	SF	Slight sulfurous odor
C'se2	172-180	N	4	1	lfs	-	NF	Slight sulfurous odor
C'se3	180+	10Y	3	-	fsl	-	SF	-

Point Judith Dredge Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	sand (%)	silt (%)	clay (%)	CF (%)	Shells (%)	Lab texture	Bulk Density (g/cm^3)
A	0	2	12	57	17	88	10	2	0	0	fs	1.16
Cg1	0	1	11	62	14	89	10	1	0	0	fs	1.42
Cg2	0	1	15	65	13	94	5	0	0	0	fs	1.37
Cg3	1	1	19	56	13	91	8	1	0	0	fs	1.27
Cg4	0	1	11	44	28	84	15	2	0	0	lfs	1.23
Aseb	0	1	8	21	33	63	34	3	0	0	vfsl	0.69
Cse	0	2	5	11	38	55	42	3	0	0	vfsl	0.87
C'g1	0	0	1	7	43	51	46	3	0	0	vfsl	0.74
C'g2	1	0	1	30	55	87	12	1	0	0	vfs	1.09
C'se1	0	1	0	16	53	71	28	2	0	0	vfsl	0.86
C'se2	0	0	1	12	72	85	14	1	0	0	lvfs	1.19
C'se3	0	0	1	9	58	68	30	2	0	0	vfsl	0.98

Point Judith Dredge Lab Data (continued)

Horizon	SOM (%)	SOC (%)	$CaCO_3$ (%)	EC 1:5 (dS m^{-1})	Initial pH	Incubation pH (16 week)	pH change
A	2.39	1.19	8.27	3.72	7.63	7.88	0.25
Cg1	1.24	0.62	4.31	2.28	7.88	8.15	0.27
Cg2	0.92	0.46	4.65	2.18	7.82	8.6	0.78
Cg3	1.14	0.57	8.49	2.25	8.19	8.6	0.41
Cg4	2.01	1.01	8.30	2.53	7.97	7.99	0.02
Aseb	6.27	3.13	14.63	4.44	7.8	2.68	-5.12
Cse	4.51	2.26	14.04	4.16	7.79	2.72	-5.07
C'g1	3.03	1.52	10.53	3.63	7.62	6.84	-0.78
C'g2	0.83	0.41	3.91	2.6	7.59	7.18	-0.41
C'se1	2.19	1.09	6.31	2.56	7.54	3	-4.54
C'se2	1.21	0.61	4.16	2.4	7.63	3.59	-4.04
C'se3	1.87	0.94	5.88	2.89	7.67	2.92	-4.75

Site: Wickford Control (Pishagqua Series)

Field Data

Horizon	Depth (cm)	Color			Field texture	Coarse Frags (%)	Fluidity Class	Notes
		Hue	Value	Chroma				
Ase	0-20	5Y	3	1	Sil	-	XF	Moderate sulfurous odor
Cse1	20-40	5Y	3	1	Sil	-	MF	Moderate sulfurous odor
Cse2	40-70	5Y	3	1	Sil	15% shells	MF	Moderate sulfurous odor; clam shells
Cse3	70-90	5Y	3	1	Sil	-	MF	Moderate sulfurous odor
Cse4	90-108	5Y	3	1	Sil	-	MF	Moderate sulfurous odor

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF (%)	Shells (%)	Lab texture	Bulk Density (g/cm^3)
Ase	0	5	13	20	22	62	21	17	0	0	fsl	0.50
Cse1	0	1	5	12	20	38	44	18	0	0	l	1.10
Cse2	2	4	10	8	7	31	50	19	0	0	sil	1.13
Cse3	5	9	13	15	15	56	30	14	0	0	fsl	1.15
Cse4	3	5	8	9	10	35	49	16	0	0	l	0.59

Wickford Control Lab Data (Continued)

Horizon	SOM (%)	SOC (%)	$CaCO_3$ (%)	EC 1:5 (dS m^{-1})	Initial pH	Incubation pH (16 week)	pH change
Ase	6.70	3.35	20.79	4.04	6.65	2.96	-3.69
Cse1	3.15	1.58	14.52	2.62	7.19	3.1	-4.09
Cse2	4.40	2.20	17.11	3.59	7.31	2.79	-4.52
Cse3	5.39	2.70	19.63	3.84	7.43	2.81	-4.62
Cse4	5.20	2.60	21.25	3.37	7.23	2.91	-4.32

Site: Wickford Dredge (Pishagqua Series)

Field Data

Horizon	Depth (cm)	Color			Field texture	Coarse Frags (%)	Fluidity Class	Notes
		Hue	Value	Chroma				
Ase	0-12	5Y	3	1	Sil	-	XF	Moderate sulfurous odor
Cse1	12-30	5Y	3	1	Sil	-	HF	Moderate sulfurous odor
Cse2	30-60	5Y	3	1	Sil	-	HF	Moderate sulfurous odor; clam shells
Cse3	60-85	5Y	3	1	Sil	-	HF	Moderate sulfurous odor
Cse4	85-105	5Y	3	1	Sil	-	MF	Moderate sulfurous odor

Lab Data

Horizon	vcos (%)	cos (%)	ms (%)	fs (%)	vfs (%)	Sand (%)	Silt (%)	Clay (%)	CF (%)	Shells (%)	Lab texture	Bulk Density (g/cm^3)
Ase	0	0	1	1	8	11	65	24	0	0	sil	0.22
Cse1	0	0	0	1	12	14	63	23	0	0	sil	0.30
Cse2	0	0	0	1	8	9	70	21	0	0	sil	0.30
Cse3	0	0	0	0	5	6	72	22	0	0	sil	0.52
Cse4	0	0	0	1	6	7	72	21	0	0	sil	0.57

Wickford Dredge Lab Data (Continued)

Horizon	SOM (%)	SOC (%)	$CaCO_3$ (%)	EC 1:5 (dS m^{-1})	Initial pH	Incubation pH (16 week)	pH change
Ase	7.64	3.82	21.91	5.32	6.85	3.43	-3.42
Cse1	7.34	3.67	23.24	4.87	7.59	2.99	-4.6
Cse2	7.83	3.92	25.45	4.86	7.9	2.91	-4.99
Cse3	7.88	3.94	25.67	4.73	8.19	2.94	-5.25
Cse4	7.94	3.97	23.51	4.69	8.34	3.21	-5.13

APPENDIX 5: Subaqueous soil macroinvertebrate inventories

Ninigret Control Benthic Macroinvertebrates

Invertebrate ID	Sample					Avg # Individuals	Density (#/m^2)	Feeding Group
	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5			
Ampeliscidae	0	2	0	0	0	0	17	Deposit Feeder
Arabella iricolor	1	0	0	0	1	0	17	Deposit Feeder
Clymenella torquata	139	168	111	121	86	125	5435	Filter Feeder
Glycera americana	1	0	0	0	0	0	9	Predator
Glycera dibranchiata	1	0	0	3	3	1	61	Predator
Leitoscoloplos fragilis	0	0	0	2	0	0	17	Deposit Feeder
Maldane sarsi	0	0	1	0	19	4	174	Deposit Feeder
Mya arenaria	2	19	11	9	6	9	409	Filter Feeder
Nematoda	0	0	0	0	1	0	9	Parasite
Paraonis fulgens	2	0	0	0	0	0	17	Deposit Feeder
Pectinaria gouldii	0	0	2	0	0	0	17	Filter Feeder
Scalibregma inflatum	0	0	0	3	1	1	35	Deposit Feeder
Species Richness:	12							
Average Total Density:	6217							

Ninigret Dredge Benthic Macroinvertebrates

Invertebrate ID	Sample					Avg # Individuals	Density (#/m^2)	Feeding Group
	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5			
Ampeliscidae	1	2	0	0	3	1	52	Deposit Feeder
Clymenella torquata	0	0	0	0	0	0	0	Filter Feeder
Glycera americana	2	0	1	0	0	1	26	Predator
Ilyanassa obsoleta	1	0	0	0	0	0	9	Deposit Feeder
Nephtys picta	1	5	1	0	3	2	87	Deposit Feeder
Species Richness:	5							
Average Total Density:	174							

Wickford Control Benthic Macroinvertebrates

Invertebrate ID	Sample					Avg # Individuals	Density (#/m^2)	Feeding Group
	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5			
Clymenella torquata	2	0	0	1	2	1	43	Filter Feeder
Gemma gemma	5	2	1	3	1	2	104	Filter Feeder
Glycera dibranchiata	1	0	0	0	0	0	9	Predator
Ilyanassa obsoleta	13	12	16	11	14	13	574	Deposit Feeder
Nematoda	0	0	1	0	0	0	9	Parasite
Species Richness:	5							
Average Total Density (#/m^2):	739							

Wickford Dredge Benthic Macroinvertebrates

Invertebrate ID	Sample					Avg # Individuals	Density (#/m^2)	Feeding Group
	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5			
Ampeliscidae	0	0	1	0	0	0	9	Deposit Feeder
Clymenella torquata	2	0	3	0	0	1	43	Filter Feeder
Gemma gemma	2	1	4	1	2	2	87	Filter Feeder
Glycera americana	0	0	1	0	0	0	9	Predator
Ilyanassa obsoleta	0	0	0	3	4	1	61	Deposit Feeder
Nematoda	0	0	1	0	0	0	9	Parasite
Species Richness:	6							
Average Total Density:	217							

APPENDIX 6: Salt marsh ditch transect pedon laboratory data

Narrow River Site 1 North Transect Physical and Chemical Properties

Distance from ditch (m)	Horizon	Horizon depth (cm)	Fiber Content (%)	Rubbed Fibers (%)	Moisture (%)	SOM %	SOC %	Bulk Density (g/cm3)	Initial pH	Incubation pH	pH Change	Electrical Conductivity (dS m^{-1})
O	Oe1	0-20	72	36	80	36.63	18.31	0.25	6.43	3.83	-2.60	2.23
	Oe2	20-34	68	36	81	36.09	18.04	0.29	7.01	3.36	-3.65	3.32
	Oe3	34-50	52	32	80	35.10	17.55	0.16	6.96	3.43	-3.53	3.37
1	Oe1	0-20	80	24	86	58.90	29.45	0.14	6.48	3.53	-2.95	3.42
	Oe2	20-32	68	20	85	52.62	26.31	0.27	7.01	3.33	-3.68	2.36
	Oa	32-50	36	8	79	32.97	16.48	0.25	7.05	2.64	-4.41	3.65
5	Oe1	0-20	84	28	84	45.07	22.53	0.13	7.13	5.68	-1.45	3.69
	Oe2	20-38	48	20	81	40.71	20.36	0.15	7.23	5.75	-1.48	3.69
	Oa	38-50	44	8	86	52.55	26.27	0.18	9.93	4.68	-5.25	3.82
15	Oe1	0-20	84	24	89	71.27	35.64	0.13	7.06	4.86	-2.20	4.30
	Oe2	20-35	44	20	78	31.49	15.75	0.28	7.11	3.09	-4.02	3.90
	Oa	35-50	48	8	84	59.84	29.92	0.16	7.02	3.99	-3.03	4.26

Narrow River Site 1 South Transect Physical and Chemical Properties

Distance from ditch (m)	Horizon	Horizon depth (cm)	Fiber Content (%)	Rubbed Fibers (%)	Moisture (%)	SOM %	SOC %	Bulk Density (g/cm3)	Initial pH	Incubation pH	pH Change	Electrical Conductivity (dS m^{-1})
O	Oe1	0-20	80	32	84	55.37	27.68	0.18	7.15	2.79	-4.36	2.29
	Oe2	20-34	64	20	82	51.88	25.94	0.21	7.33	4.18	-3.15	2.21
	Oa	34-50	60	12	83	48.84	24.42	0.21	7.10	5.66	-1.44	2.13
1	Oe1	0-20	60	32	86	69.43	34.71	0.16	7.18	3.63	-3.55	3.50
	Oe2	20-33	56	20	79	38.10	19.05	0.18	7.25	3.90	-3.35	2.53
	Oa	33-50	52	12	79	37.58	18.79	0.21	7.14	3.14	-4.00	2.21
5	Oe1	0-20	72	28	87	61.10	30.55	0.11	6.83	3.01	-3.82	3.62
	Oe2	20-31	56	20	78	34.18	17.09	0.23	7.71	3.98	-3.73	3.53
	Oa	31-50	28	8	78	30.48	15.24	0.17	7.36	5.23	-2.13	3.10
15	Oe1	0-20	84	24	86	62.38	31.19	0.10	7.22	5.97	-1.25	4.08
	Oe2	20-36	68	20	84	55.00	27.50	0.23	7.16	4.19	-2.97	3.61
	Oa	36-50	48	12	77	28.18	14.09	0.21	7.35	5.39	-1.96	3.54

Narrow River Site 2 South Transect Physical and Chemical Properties

Distance from ditch (m)	Horizon	Horizon depth (cm)	Fiber Content (%)	Rubbed Fibers (%)	Moisture (%)	SOM %	SOC %	Bulk Density (g/cm3)	Initial pH	Incubation pH	pH Change	Electrical Conductivity (dS m^{-1})
0	Oe1	0-19	56	28	73	31.31	15.66	0.20	6.65	2.28	-4.37	5.37
	Oe2	19-38	44	20	70	26.31	13.16	0.34	6.84	3.68	-3.16	4.73
	Oa1	41-50	52	12	67	26.04	13.02	0.27	7.05	4.77	-2.28	5.13
	Oa2	38-41	40	8	77	42.70	21.35	0.56	6.68	4.33	-2.35	5.54
1	Oe	0-20	52	28	76	40.18	20.09	0.18	7.01	2.58	-4.43	4.23
	Cg1	20-36	38	12	65	22.36	11.18	0.33	6.23	1.99	-4.24	4.15
	Cg2	36-44	44	8	41	6.53	3.26	0.20	6.34	2.33	-4.01	5.22
	Oab	44-50	48	8	73	33.25	16.63	0.62	6.38	3.36	-3.02	5.85
5	Oa	0-21	52	16	77	37.40	18.70	0.16	6.50	5.18	-1.32	5.09
	Cg1	21-24	56	12	68	21.41	10.71	0.20	7.07	4.09	-2.98	3.58
	Cg2	24-45	44	8	43	7.49	3.75	0.25	6.93	5.09	-1.84	4.17
	Cg3	45-50	40	8	65	22.25	11.13	0.25	6.84	4.27	-2.57	3.82
15	Oe1	0-20	56	28	82	59.71	29.86	0.17	5.57	3.96	-1.61	4.58
	Oe2	20-36	72	28	80	45.15	22.57	0.23	7.38	3.95	-3.43	4.87
	Oa	36-44	52	12	73	29.55	14.78	0.27	7.19	4.83	-2.36	4.51
	Cg	44-50	40	8	50	10.43	5.22	0.28	7.09	2.62	-4.47	4.49

Narrow River Site 3 North Transect Physical and Chemical Properties

Distance from ditch (m)	Horizon	Horizon depth (cm)	Fiber Content (%)	Rubbed Fibers (%)	Moisture (%)	SOM %	SOC %	Bulk Density (g/cm3)	Initial pH	Incubation pH	pH Change	Electrical Conductivity (dS m^{-1})
0	Oe	0-20	56	32	68	26.03	13.01	0.37	6.33	2.91	-3.42	3.68
	Cg1	20-30	60	24	63	19.72	9.86	0.29	6.96	2.37	-4.59	2.93
	Cg2	30-46	52	20	64	20.02	10.01	0.24	6.89	2.90	-3.99	1.14
	Oab	46-50	48	12	88	79.77	39.88	0.23	7.11	2.64	-4.47	0.86
1	Oe1	0-18	60	28	77	34.51	17.25	0.21	6.74	3.86	-2.88	3.91
	Oe2	18-32	48	20	65	24.50	12.25	0.23	6.83	2.27	-4.56	2.53
	Oe3	32-45	60	24	75	30.77	15.39	0.27	7.08	2.28	-4.80	1.80
	Oa	45-50	52	12	88	79.92	39.96	0.15	7.01	2.64	-4.37	1.91
5	Oe	0-15	80	40	82	57.71	28.85	0.15	5.62	2.98	-2.64	4.30
	Cg	15-20	36	12	58	13.56	6.78	0.33	6.91	3.23	-3.68	3.63
	Oeb1	20-43	68	20	80	43.82	21.91	0.16	7.13	2.54	-4.59	1.28
	Oeb2	43-50	48	12	84	51.75	25.88	0.39	6.97	4.68	-2.29	1.33
15	Oe	0-19	84	40	81	63.56	31.78	0.19	4.28	3.56	-0.72	5.27
	Cg	19-23	36	12	38	4.84	2.42	0.39	7.13	4.48	-2.65	4.24
	Oab1	23-40	48	16	83	56.85	28.43	0.15	7.17	3.61	-3.56	4.22
	Oab2	40-50	44	12	79	55.44	27.72	0.22	7.32	3.14	-4.18	3.64

Narrow River Site 3 South Transect Physical and Chemical Properties

Distance from ditch (m)	Horizon	Horizon depth (cm)	Fiber Content (%)	Rubbed Fibers (%)	Moisture (%)	SOM %	SOC %	Bulk Density (g/cm3)	Initial pH	Incubation pH	pH Change	Electrical Conductivity (dS m^{-1})
0	Oe	0-20	84	36	69	37.40	18.70	0.26	6.05	2.72	-3.33	2.68
	Cg	20-31	36	12	62	18.80	9.40	0.49	5.74	2.48	-3.26	2.15
	Oab1	31-45	52	16	75	33.11	16.55	0.27	7.06	2.12	-4.94	1.88
	Oab2	45-50	48	12	76	33.31	16.66	0.24	7.08	4.89	-2.19	1.67
1	Oe	0-15	72	36	68	23.75	11.87	0.24	5.61	3.60	-2.01	4.17
	Cg	15-20	36	20	57	15.93	7.97	0.45	5.93	2.20	-3.73	2.36
	Oab1	20-35	56	16	77	40.58	20.29	0.25	6.68	2.50	-4.18	2.24
	Oab2	35-50	56	12	70	26.96	13.48	0.25	6.76	2.30	-4.46	2.04
5	Oe	0-17	80	32	81	55.85	27.93	0.14	6.96	5.27	-1.69	4.58
	Cg	17-21	40	24	46	8.26	4.13	0.35	5.74	2.48	-3.26	3.19
	Oeb	21-41	64	28	79	42.07	21.03	0.19	7.06	3.37	-3.69	3.29
	Oab	41-50	36	8	78	35.11	17.55	0.17	7.08	2.33	-4.75	2.79
15	Oe	0-18	92	44	82	69.98	34.99	0.12	4.45	2.55	-1.90	5.27
	Cg	18-21	36	12	66	18.33	9.16	0.28	6.71	4.31	-2.40	4.24
	Oab1	21-36	56	20	81	40.07	20.03	0.14	7.30	4.13	-3.17	4.22
	Oab2	36-50	52	16	76	34.50	17.25	0.30	7.22	3.23	-3.99	3.64

Winnapaug Site 1 East Transect Physical and Chemical Properties

Distance from ditch (m)	Horizon	Horizon depth (cm)	Fiber Content (%)	Rubbed Fibers (%)	Moisture (%)	SOM %	SOC %	Bulk Density (g/cm3)	Initial pH	Incubation pH	pH Change	Electrical Conductivity (dS m^{-1})
0	Oe	12	50	28	59	22.47	11.23	0.30	6.43	6.07	-0.36	5.26
	Cg1	20	-	NA	30	2.70	1.35	0.71	6.35	2.05	-4.30	3.88
	Oeb	28	36	20	72	19.85	9.92	0.22	6.48	2.83	-3.65	6.42
	Cg'1	41	-	NA	37	2.31	1.15	0.81	6.77	1.86	-4.91	2.12
	Cg'2	50+	-	NA	21	0.57	0.28	1.14	7.72	1.97	-5.75	1.52
1	Oe1	9	36	20	75	27.20	13.60	0.23	6.54	5.41	-1.13	6.72
	Oe2	29	36	20	77	52.81	26.40	0.20	6.62	3.63	-2.99	7.88
	Cg1	39	-	NA	25	2.06	1.03	1.01	7.19	2.05	-5.14	2.59
	Cg2	50+	-	NA	22	0.75	0.37	1.02	7.06	2.10	-4.96	1.91
5	Oa	9	28	12	81	38.36	19.18	0.16	5.84	4.50	-1.34	7.21
	Oe	29	52	24	82	39.27	19.63	0.12	5.72	3.57	-2.15	7.07
	Cg1	42	-	NA	37	3.66	1.83	0.81	6.86	2.34	-4.52	3.32
	Cg2	50+	-	NA	24	1.27	0.64	0.87	7.24	2.00	-5.24	2.09
15	Oa	7	20	8	80	30.18	15.09	0.15	6.38	5.69	-0.69	7.46
	Oe	26	46	24	82	39.38	19.69	0.16	6.44	3.88	-2.56	7.04
	Cg1	43	-	NA	26	2.68	1.34	0.89	6.55	2.17	-4.38	3.59
	Cg2	50+	-	NA	20	0.49	0.25	0.99	7.18	2.70	-4.48	2.33

Winnapaug Site 1 West Transect Physical and Chemical Properties

Distance from ditch (m)	Horizon	Horizon depth (cm)	Fiber Content (%)	Rubbed Fibers (%)	Moisture (%)	SOM %	SOC %	Bulk Density (g/cm3)	Initial pH	Incubation pH	pH Change	Electrical Conductivity (dS m^{-1})
0	Oa	9	42	24	81	35.72	17.86	0.15	6.66	6.26	-0.40	6.62
	Oe	24	40	28	56	18.72	9.36	0.39	6.28	3.07	-3.21	6.74
	Cg1	41	-	NA	24	1.40	0.70	1.20	7.27	2.21	-5.06	1.59
	Cg2	50+	-	NA	20	0.48	0.24	1.01	7.37	2.10	-5.27	1.53
1	Oa	9	36	20	70	23.82	11.91	0.23	6.48	6.30	-0.18	7.42
	Oe	27	36	20	81	37.72	18.86	0.12	5.80	3.69	-2.11	7.75
	Cg1	43	-	NA	33	2.40	1.20	0.67	7.37	1.96	-5.41	2.64
	Cg2	50+	-	NA	19	0.42	0.21	0.78	7.47	2.08	-5.39	1.71
5	Oa	9	10	2	82	43.53	21.77	0.09	6.11	4.19	-1.92	10.36
	Oe	26	50	32	83	38.24	19.12	0.10	6.93	3.84	-3.09	8.33
	Cg1	42	-	NA	28	2.67	1.33	1.14	7.76	2.02	-5.74	2.43
	Cg2	50+	-	NA	20	0.56	0.28	1.05	7.62	2.27	-5.35	2.35
15	Oa	7	10	4	82	38.91	19.46	0.12	7.08	7.07	-0.01	9.48
	Oe	24	50	28	80	37.82	18.91	0.14	6.97	5.59	-1.38	8.39
	Cg1	42	-	NA	23	1.92	0.96	1.21	7.13	4.29	-2.84	3.17
	Cg2	50+	-	NA	21	0.54	0.27	0.71	7.25	3.89	-3.36	2.42

Winnapaug Site 2 East Transect Physical and Chemical Properties

Distance from ditch (m)	Horizon	Horizon depth (cm)	Fiber Content (%)	Rubbed Fibers (%)	Moisture (%)	SOM %	SOC %	Bulk Density (g/cm3)	Initial pH	Incubation pH	pH Change	Electrical Conductivity (dS m^{-1})
0	Oa1	14	36	16	75	40.30	20.15	0.20	6.78	5.23	-1.55	6.18
	Oa2	27	32	16	84	63.77	31.88	0.10	6.41	2.66	-3.75	6.90
	Cg	50+	-	-	28	3.85	1.92	0.89	7.59	2.38	-5.21	3.30
1	Oe	14	40	20	83	0.00	0.00	0.16	5.77	3.47	-2.30	6.71
	Oa	32	36	16	79	48.66	24.33	0.14	7.03	3.23	-3.80	7.78
	Cg	50+	-	-	28	41.87	20.93	0.86	6.99	2.26	-4.73	2.59
5	Oe1	14	52	24	83	3.08	1.54	0.13	6.95	4.59	-2.36	7.71
	Oe2	33	36	20	83	0.00	0.00	0.13	7.09	4.23	-2.86	7.69
	Cg	50+	-	-	23	56.24	28.12	1.03	7.15	2.45	-4.70	2.41
15	Oa1	14	28	8	82	47.23	23.62	0.11	6.73	4.73	-2.00	8.88
	Oa2	40	32	8	85	2.87	1.44	0.12	7.28	5.05	-2.23	8.27
	Cg	50+	-	-	30	0.00	0.00	0.99	7.12	2.33	-4.79	4.31

Winnapaug Site 2 West Transect Physical and Chemical Properties

Distance from ditch (m)	Horizon	Horizon depth (cm)	Fiber Content (%)	Rubbed Fibers (%)	Moisture (%)	SOM %	SOC %	Bulk Density (g/cm3)	Initial pH	Incubation pH	pH Change	Electrical Conductivity (dS m^{-1})
0	Oa	13	32	16	76	44.35	22.18	0.18	5.88	4.58	-1.30	7.39
	CA	22	-	-	51	62.30	31.15	0.36	6.13	2.78	-3.35	3.37
	Oab	37	32	16	79	2.76	1.38	0.19	6.88	4.32	-2.56	6.53
	Cg	50+	-	-	28	0.00	0.00	1.03	7.27	2.47	-4.80	3.15
1	Oe	17	36	20	79	49.23	24.62	0.17	4.08	3.59	-0.49	8.93
	Oa	36	32	12	82	9.19	4.60	0.15	6.76	3.23	-3.53	8.20
	Cg	50+	-	-	27	33.12	16.56	1.09	7.54	2.64	-4.90	2.46
5	Oe	17	44	24	81	2.86	1.43	0.13	6.38	3.81	-2.57	10.83
	Oa	37	40	8	73	0.00	0.00	0.22	7.11	4.35	-2.76	8.72
	Cg	50+	-	-	28	48.52	24.26	0.79	7.68	2.84	-4.84	2.49
15	Oa1	18	32	12	83	44.75	22.37	0.10	6.69	5.10	-1.59	9.58
	Oa2	38	32	8	84	2.98	1.49	0.12	7.04	5.05	-1.99	9.30
	Cg	50+	-	-	33	0.00	0.00	0.97	7.35	2.68	-4.67	2.60

Winnapaug Site 3 East Transect Physical and Chemical Properties

Distance from ditch (m)	Horizon	Horizon depth (cm)	Fiber Content (%)	Rubbed Fibers (%)	Moisture (%)	SOM %	SOC %	Bulk Density (g/cm3)	Initial pH	Incubation pH	pH Change	Electrical Conductivity (dS m^{-1})
0	A	11	48	24	58	12.27	6.13	0.45	6.24	4.38	-1.86	7.16
	AC	15	20	12	49	13.02	6.51	0.34	6.17	2.39	-3.78	6.33
	Oab	36	32	8	82	47.36	23.68	0.11	6.38	3.89	-2.49	8.28
	Cg	50+	-	-	21	1.86	0.93	1.07	6.25	1.95	-4.30	4.33
1	Oe	16	56	20	82	43.28	21.64	0.14	6.43	3.55	-2.88	8.62
	Oa	34	28	12	75	24.07	12.04	0.20	6.61	4.24	-2.37	7.86
	Cg	50+	-	-	26	4.15	2.08	1.06	6.81	1.86	-4.95	4.59
5	Oe	17	68	32	84	53.04	26.52	0.13	6.88	4.25	-2.63	11.38
	Oa	35	52	16	22	45.25	22.63	0.16	7.00	4.60	-2.40	11.03
	Cg	50+	-	-	79	2.28	1.14	1.13	7.30	1.94	-5.36	3.48
15	Oe	18	44	20	83	60.06	30.03	0.11	6.91	4.56	-2.35	10.30
	Oa	33	52	12	81	43.20	21.60	0.13	6.89	4.18	-2.71	13.10
	Cg	50+	-	-	29	3.45	1.72	1.02	6.90	2.36	-4.54	3.89

Winnapaug Site 3 West Transect Physical and Chemical Properties

Distance from ditch (m)	Horizon	Horizon depth (cm)	Fiber Content (%)	Rubbed Fibers (%)	Moisture (%)	SOM %	SOC %	Bulk Density (g/cm3)	Initial pH	Incubation pH	pH Change	Electrical Conductivity (dS m^{-1})
0	Oe	19	36	20	65	23.66	11.83	0.25	6.61	4.16	-2.45	6.68
	Oa	34	20	8	83	45.77	22.88	0.14	6.32	3.13	-3.19	7.85
	Cg	50+	-	-	19	2.20	1.10	1.16	6.29	2.13	-4.16	3.62
1	Oe	17	48	28	77	37.38	18.69	0.16	6.77	6.26	-0.51	8.06
	Oa	35	32	12	83	45.90	22.95	0.13	6.55	2.84	-3.71	8.12
	Cg	50+	-	-	19	1.64	0.82	1.14	6.45	2.51	-3.94	3.21
5	Oe	19	68	32	82	42.01	21.01	0.15	6.56	4.73	-1.83	9.29
	Oa	38	52	8	82	32.54	16.27	0.15	6.48	5.17	-1.31	9.02
	Cg	50+	-	-	25	2.86	1.43	1.02	6.79	2.71	-4.08	3.67
15	Oe	17	68	32	81	47.20	23.60	0.13	6.75	4.57	-2.18	9.66
	Oa	36	52	12	81	43.56	21.78	0.15	6.65	2.93	-3.72	9.99
	Cg	50+	-	-	30	3.41	1.71	0.88	6.71	1.95	-4.76	3.99

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