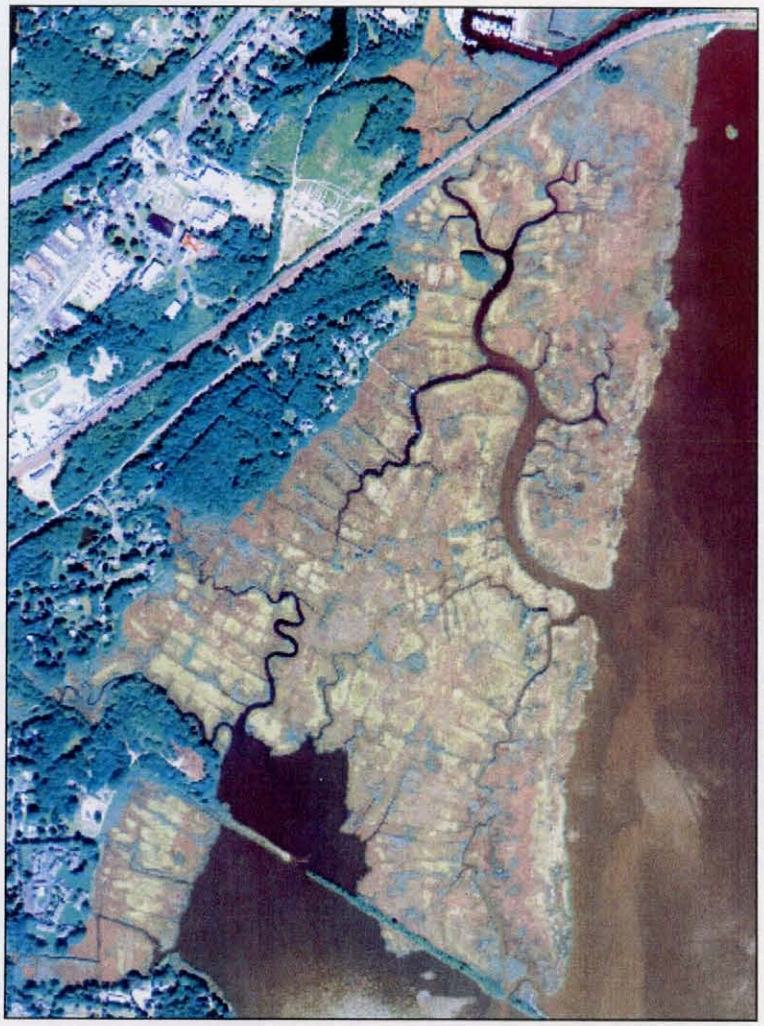
THE VEGETATION MOSAIC OF RAGGED ROCK CREEK BRACKISH TIDAL MARSH, CONNECTICUT RIVER, OLD SAYBROOK, CT

A FINAL REPORT TO
DEPARTMENT OF ENVIRONMENTAL PROTECTION, STATE OF CONNECTICUT



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ABSTRACT/SUMMARY

This study used the detailed plots-based floristic descriptions of traditional phytosociology to inform scenes of high resolution imagery to characterize and map, in detail, the brackish tidal wetland plant communities of Ragged Rock Creek. An emphasis was placed on providing a baseline geographic context for plants of conservation and management interest, *i.e.,* both state-listed plants and invasive plants. The results provided a baseline vegetation assessment and map prior to invasive *Phragmites australis* (common reed) control and restoration by onsite re-vegetation. Representative samples of 10 major community types, derived from hierarchical cluster analysis and fidelity tests, were used to determine the spectral profiles from high resolution ADS40 RBG/CIR images and LiDAR top of canopy return, that in turn, were used to inform an object-based software technique to generate a detailed vegetation map. The map was validated using a conventional contingency table approach, with mixed results, mostly coinciding with the frequency and size of the community patch. Our dense array of 926 precisely georeferenced plots, photographs, quantitative vegetation data, and voucher specimens, provide a robust baseline which will enable an evaluation of the marsh response in the future to management, climate change, sea-level rise, or other phenomena. This study demonstrated the utility of this approach for mapping large and heterogeneous wetland complexes and taking baselines for management and monitoring actions.

INTRODUCTION

Within the estuarine reaches of the lower Connecticut River, where saline tides mix with freshwater discharge, are found unique and interesting "Brackish" tidal wetlands. The brackish environment of the tidal wetland habitat allows for a diverse mix of plants and animals, some of which thrive here and/or may not be found elsewhere. The biological diversity and unique habitat value of the lower Connecticut River brackish tidal wetlands is well-known (TNC 1993, Dreyer and Caplis 2001, Ramsar 2008). Subsequently, threats to the integrity of these brackish tidal wetlands is of concern, such as various types of anthropogenic modifications, like

surrounding development, global sea level rise, and invasive species (Dreyer and Niering 1995, Ashton et al. 2008). Of immediate concern, is the extensive invasion of the non-native genotype of *Phragmites australis* (Cav.) Trin. *ex* Steud. (Dreyer and Niering 1995, Barrett and Prisloe 1998, Chambers et al. 1999, Burdick et al. 2001). Non-native *Phragmites* is very competitive in less saline conditions such as brackish tidal wetlands (Chambers et al. 1999, Burdick et al. 2001).

To address the problem of increasing *Phragmites*, a consortium of several government agencies, academic institutions, and private conservation groups have organized to focus efforts to eradicate *Phragmites* and restore the tidal wetlands of the lower Connecticut River. One of the emerging strategies was to conduct assessments of the tidal wetland vegetation to guide and monitor the effectiveness of the *Phragmites* control and other habitat management activities. Monitoring efforts have mostly focused on spatially limited but detailed plot-based floristic studies and to a lesser degree on spatially extensive, but generalized remote sensing investigations or aerial inspections. Furthermore, restoration monitoring has largely been concerned whether the re-emergent plants are either *Phragmites* or not, with less consideration to what the plant biodiversity is or how plants were organized into vegetation types. Although recent advances have been made in conducting remote vegetation assessments (Gilmore et al. 2008), an opportunity exists to summarize the floristic inventories into recognizable plant community types and use the vegetation descriptions to better inform the remote sensing analyses.

Ragged Rock Creek is one of the largest brackish tidal wetland systems in the Connecticut River estuary with vegetation that is considered relatively intact *i.e.,* it hat has suffered the least incursion of *Phragmites* (Barrett and Prisloe 2001). Plans for eradicating *Phragmites* and allowing the marsh vegetation to restore itself have been made by the Wildlife Division of The State Department of Environmental Protection (CT-DEP), The Nature Conservancy (TNC), and the Natural Resources Conservation Service (NRCS). A before & after assessment was recommended to better measure the restoration success and that would also meet the monitoring requirement of the NRCS' Wetlands Reserve Program (WRP). Therefore, Ragged Rock Creek is ideally suited for just such an assessment project that aims to extensively measure, model, map, and monitor vegetation. Albeit, vegetation assessment projects are not limited only to monitoring restorations, but may include evaluating responses to sea-level rise, and other phenomena.

The purpose of this study was to unite techniques of remote sensing with vegetation science into a novel approach. This approach combined the extensive high resolution image data with concentrated, detailed field descriptions, together, into an integrated, semi-automated routine that characterized and mapped the brackish tidal wetland plant communities of Ragged Rock Creek. This integrated routine avoided the limitations of separate approaches to vegetation description and mapping. For example, the vegetation maps conveyed more detailed information than conventional interpretations of this scale that merely describe simple cover-types or unknown photo-analogs of vegetation. And, the detailed vegetation survey was geographically extrapolated beyond the spatial limits of the field plots. The specific objectives were to:

1) Conduct an extensive plot-based floristic baseline inventory with photo documentation, taking particular emphasis on species of conservation interest, *e.g.*, state-listed plants, and invasive species, particularly *Phragmites australis*,

2) Perform a quantitative phytosociological analysis to summarize the sampled vegetation into differentiated plant community types,

3) Model the spatial and spectral characteristics of representative samples of plant community types using an object-oriented imagery analysis of several, high-resolution scenes,

4) Derive a detailed map adequately depicting the identity and spatial extent of the classified vegetation types.

5) Conduct a accuracy analysis of validation plots using the conventional contingency (confusion) matrix.

6) Reconcile the classified vegetation types of Ragged Rock Creek brackish tidal wetlands from this study with the results reported from other studies.

Figure 1. Ragged Rock Creek brackish tidal wetland study area

Description of the Study Area

The Study area at Ragged Rock Creek marsh is a 136 hectare brackish tidal marsh located on the western shore of the Connecticut River, approximately 2.5 km north of its confluence with Long Island Sound in the Town of Old Saybrook (Figure 1). Located within estuarine reaches of the lower Connecticut River, changes in floodwater salinity, tidal inundation, and disturbances from seasonal and storm-event floods as well as human modifications create a variety of habitat conditions resulting in a vegetation mosaic that is also quite spatially variable (TNC 1993, Barrett and Barrett 1997). The surface salinity of open waters at Ragged Rock Creek varies seasonally with discharge and varies semidiurnally with the tides, ranging from nearly fresh to brackish (or mixohaline), 0.5 to <30 PSU [Practical Salinity Units (UNESCO 1981)] (Garvine 1994). The tidal range at the closest station at the Highway Bridge in Lyme is reported at a 1.01 m mean range and 1.19 m spring range with a mean tide level at 0.56 m (NOAA CO-OPS 2009). The soils are mapped as Westbrook mucky-peat low salt (NRCS 2009b). Disturbances to the marsh associated with seasonal or events of high water facilitating the deposition of materials including flotsam. Human modifications to the marsh include mosquito ditching to all but the section north and east of Ragged Rock Creek.

The appearance of the vegetation at Ragged Rock Creek marsh is a complex mosaic, (Nichols 1920, Metzler and Rozsa 1982, Barrett 1989, Gilmore et al. 2008) ranging from patches of monospecific plant dominants with discrete boundaries, to mixed-species patches with more diffuse transitions. Of particular significance is the exponential increase in the spatial extent and dominance of the invasive plant, *Phragmites australis* (Barrett and Prisloe 1998).

METHODS & DATA PROCESSING

Ficld Sampling

A floristic inventory of the tidal wetlands of Ragged Rock Creek was conducted during the summer of 2006 to describe the plant communities, and establish validation data for image mapping. Using a stratified approach to insure adequate sampling across the marsh in marginal and common environments, a set of 1,000 randomly distributed sample point-locations was generated using Hawth's Analysis Tools for ArcGIS (Beyer 2004)). A large number of sample plots were desired to achieve a suitable hierarchical classification scheme that could distinguish among major brackish plant community-types as well as identify any nested variation as mixed-types. In addition, a large number of plots were necessary to sufficiently define a training set for object classification and mapping (Definiens 2007). During the course of the study several predetermined sample locations were abandoned for practical reasons, *e.g.*, open water locations, disturbed by mowing, or boardwalk/dock intersections. Conversely, a small number (53) of locations were added for sampling to document unique and uncommon plant species. A few plots, including those plots sampled early, were resampled to augment the data. The total number of sampled plots was 926 (Figure 2).

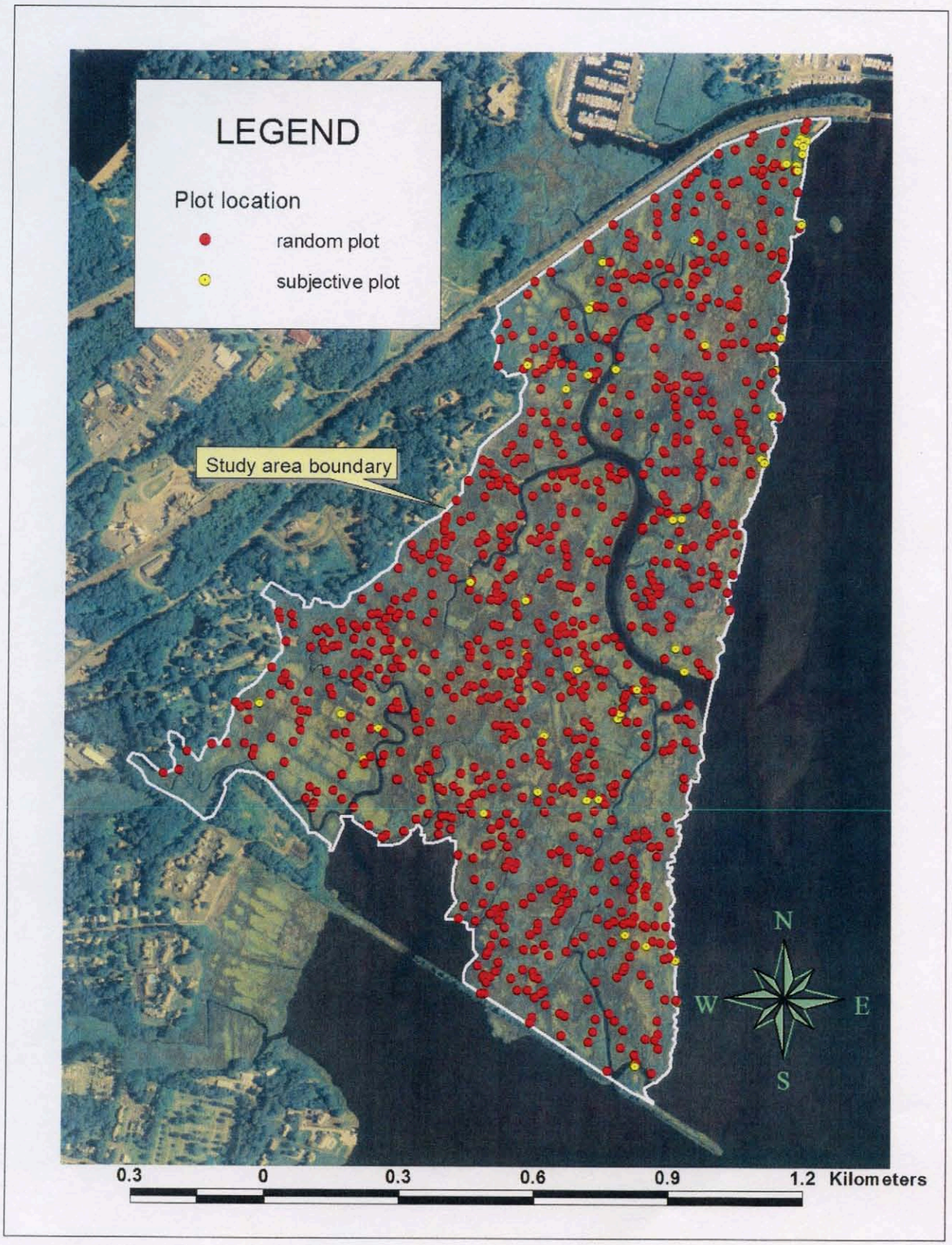

Figure 2. Locations of 926 sample plots used in the wetland vegetation assessment.

Centered at each plot location, a 4 m^2 square quadrat, the recommended plot size for tall grass/herbs shrub lifeforms (Cain and Castro 1959, Kent and Coker 1994), was used to record vegetation data. Vascular plant species composition, prevailing species height, percent cover using visual estimates (referenced to a graduated plot frame), and sociability index were recorded (Damman 1977). Additional information taken at each location included any cover attributed to bare ground, flotsam, litter, or water. Notes include the type of habitat encountered: levee, marsh, backmarsh, panne, ditch, or stream bank. Also noted was the nature of any discreet vegetation change, *e.g.*, border (abrupt turnover within plot), edge (abrupt turnover just outside the plot), or transition (gradual turnover exceeding the plot width). GPS field coordinates for the center of each sampling plot were recorded and differentially corrected. Photo documentation of the plot vegetation included an overall context shot of the plot and surroundings and a macro shot of the plot interior taken from above.

Approximately 450 voucher specimens were collected and depositions made to the G. Safford Torrey Herbarium [CONN] at the University of Connecticut, Storrs, CT. Plant nomenclature is ascribed to published volumes of the Flora of North America Project (Flora of North America Association 1993+) and the PLANTS database (NRCS 2009a).

Phytosociological Analysis

Prior to analysis, plant species' percent cover values were proportionately relativized and square-root transformed. Proportional relativization was applied to species cover among sample plots to correct for any variation in the total plot cover value that might be attributed to overlapping-cover increases over the sampling period as well as to compensate for slight variations in observer bias. Albeit, since the total coefficient-of-variation (CV) among the plot cover totals was small, 0.3, the corresponding effect of relativization upon the analysis was minimal. The square-root transformation was applied to effectively reduce the overwhelming influence of species dominance and increase the influence of subordinate species in the analysis.

The vegetation classification was accomplished using an agglomerative, hierarchical clustering technique based on pairwise Squared Euclidean Distance, SED measures, combined with the "within-group average" variant of the Unweighted Pair Group Method using Arithmetic averages, UPGMA, strategy (SPSS 2008). The resemblance measure, SED, was chosen because it has a straightforward interpretation and the squaring function emphasizes between group differences. Furthermore, the compatible, combinatorial strategy of "within-group average" in UPGMA emphasizes within-group homogeneity and has the added benefit of being amenable to creating groups of widely different sizes.

Evaluating the hierarchical classification was done independently using the Indicator Value method (Dufrêne and Legendre 1997, Legendre and Legendre 1998). Common to traditional phytosociology, species' concentrations for a given cluster were identified by significantly greater indicator values scores. The Indicator Value method was also used as an objective tool to determine what was the optimal number of final groups, *i.e.*, as a "stopping rule" for which level of the dendrogram in the hierarchical cluster analysis. As an overall measure of species group fidelity, a change in indicator value scores for successive numbers of

clusters will peak at the most informative level of clustering plant community types. Additional peaks, at greater levels of subdivision, were analyzed to further recognize subgroups representing a greater biodiversity of "mixed" vegetation types.

A complete account of the hierarchical classification was presented in a two-way table of plots-by-spies, dendrogram, and cluster membership. By phytosociological convention, the classified plant community types were named from the plant species with the greatest "fidelity" revealed by indicator value. (Mueller-Dombois and Ellenberg 1974.). An overview of the floristic dissimilarities among the classified vegetation types was presented in a synoptic table on the basis of fidelity, constancy, and percent-cover.

Types of Imagery and LiDAR

Imagery used for the mapping exercise was: 1) ADS40 (Airborne Digital Sensor) imagery in true color, RGB, and false-color infrared, CIR, dated 20-22 September 2004 with a ground resolution of 0.5 m and horizontal accuracy of 0.27 m; and 2) multiple return LiDAR (Light Detection And Ranging) data, dated 8 October 2004 with a ground resolution of 0.9 m and horizontal accuracy of 0.5 m.

All data were converted to a 0.5 m resolution grid and re-projected into the UTM coordinate system, WGS84 datum, zone 18, meters. The elevation grid was converted to an 8-bit unsigned integer format for use in the Definiens Developer software. The elevation grid using first return approximated the top of the plant canopy within the study area.

Vegetation Mapping

Vegetation mapping was achieved using the object-oriented image analysis software Definiens Developer v7.0 (Definiens 2007) and ArcGIS(ESRI 1999-2008). Definiens allows for a variety of image and other data types to be added as input layers to a project file. Input data consisted of ADS40 single date images using CIR and RGB bands as well as band ratios with demonstrated success (Gilmore et al. 2008) and LiDAR top of canopy information. A polygon of the Ragged Rock Creek marsh was created and used to mask non-marsh features such as houses, trees and lawns from the input data. A segmentation routine was used to create image objects, which are contiguous pixels grouped into homogenous polygon features. Each input layer was given equal weight in the segmentation process. Spectral and spatial parameters (smoothness and compactness) were set at 90 and 10 percent, respectively. The relative size of the segments was determined approximately, by trial–and-error, to work best at a scale parameter of 20 to fit with the imagery and detail of the desired classification. The result is a segmented image of objects and their component pixels. This object-based classification contrasts with classifiers that use only pixels (Definiens 2007).

The classified vegetation map was generated in Definiens by creating sample object segments to represent each of the seven vegetation classes and then using those samples to classify the rest of the marsh. The samples determine the spectral profile that defines each class. Spectral properties of each class are used to determine the classification for non sample image objects. Sixty-four sampling plots were used to identify training samples. Sample plots were

chosen based on their vegetative composition. Plots that represented the most homogeneous vegetative communities were used as sample sites. The spectral signature of these sample sites was used to determine additional sample segments in Definiens. A total of 181 sample image object segments were used to create the seven class map. The resulting class profiles were then used to assign identities to the rest of the segmented image objects and compile the final vegetation map. The vegetation map was produced in only one iteration, and would be considered a first approximation. The Definiens vegetation map output was exported to ArcGIS for map construction and manipulation.

Accuracy analysis – Confusion matrix *Kappa*

Over three-fourths of the field plots (n = 720) were used as validation plots for an accuracy assessment. Plots were excluded as validation plots if located near a border or if the plot was considered a poor (extreme) example of the classified community type. A conventional accuracy assessment was calculated on a pairwise basis with a standard confusion matrix and *Kappa* statistic.

RESULTS & DISCUSSION

In total, 914 vegetation plots and 77 species (including a taxonomic category for "wrack") were surveyed and used to classify the vegetation at Ragged Rock Creek brackish tidal marsh (excluding 6 plots as outliers with 30 associated species). Photo documentation of all plots is detailed individually in the Appendix.

Fidelity analysis recognized that the 10-cluster stage of the hierarchical cluster analysis was the most informative, identifying the major plant community types (Figure 1) with further subdivisions of mixed types at the 25 cluster stage possible. Futher jumps in the indicator value scores at higher cluster levels were insignificant.

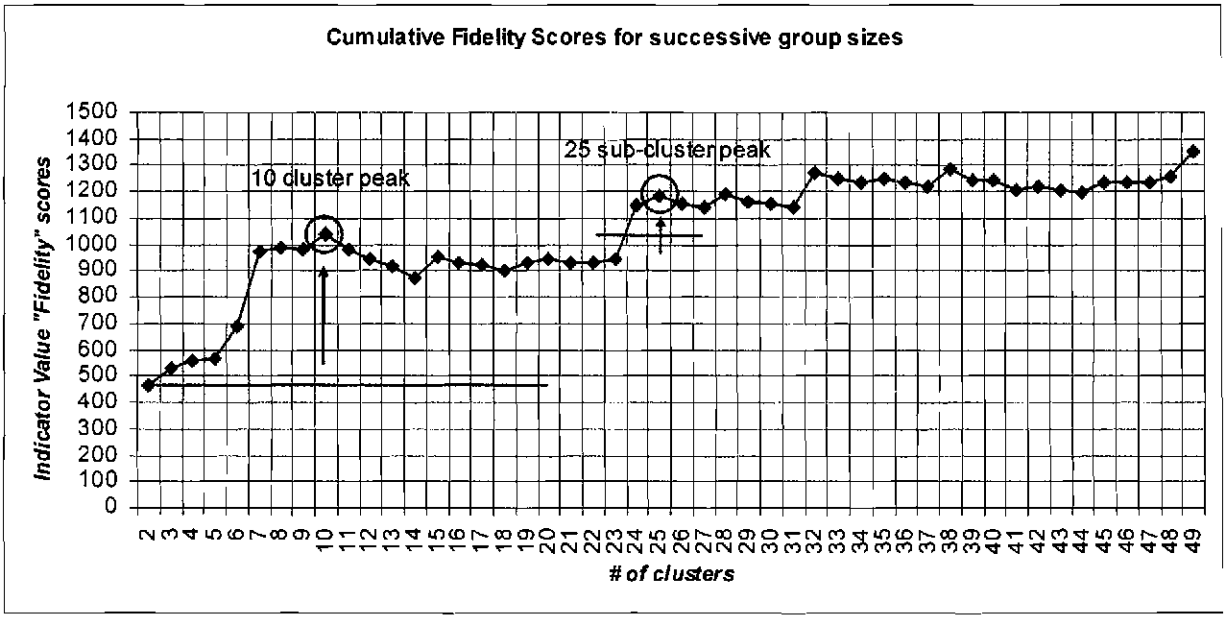

Figure 3. The 10 cluster level of the hierarchical analysis provided the optimal homogeneity for group composition based on the indicator value method of fidelity analysis. A second peak at 25 clusters also shows a slight addition in information suggested the possibility of subdiving the major 10 community types.

Each community type was named after a component plant species with the greatest fidelity (Table 1). Designated names (and abbreviations) given to the community types are presented in the SMALL CAPS font style as to not confuse the community types with accounts of individual species.

Table 1. Classified Plant Community types of Ragged Rock Creek tidal marsh

10 cluster level

25 cluster level

1. *SPARTINA PATENS* Community-Type (n = 311)
   - 1.1 *SPARTINA PATENS* / (MIX) Subtype
   - 1.2 *SPARTINA PATENS / ELEOCHARIS UNIGLUMUS* Subtype
   - 1.3 *SPARTINA PATENS / TYPHA ANGUSTIFOLIA* subtype (transitional)
   - 1.4 *SPARTINA PATENS / PHRAGMITES AUSTRALIS* (invasive) Subtype (transitional)
   - 1.5 *SPARTINA PATENS / SCHEONOPLECTUS AMERICANUS* Subtype (transitional)
   - 1.6 *IVA FRUTESCENS* / (S.P. - MIX) Subtype
2. *PANICUM VIRGATUM* Community Type (n = 15)
3. *JUNCUS GERARDII* Community Type (n = 24)
   - 3.1 *JUNCUS GERARDII* / (FORB MIX) Subtype
   - 3.2 *JUNCUS GERARDII / ARGENTINA ANSERINA* Subtype
   - 3.3 *JUNCUS GERARDII / PHRAGMITES AUSTRALIS* (invasive) Subtype (transitional)
4. *SCHOENOPLECTUS AMERICANUS* Community Type (n = 62)
   - 4.1 *SCHOENOPLECTUS AMERICANUS* / (MIX) Subtype

4.2 *SCHOENOPLECTUS AMERICANUS / TYPHA ANGUSTIFOLIA* (± *PHRAGMITES AUSTRALIS* (invasive)) Subtype (transitional)

5. *BOLBOSCHOENUS ROBUSTUS* Community Type (n = 20)
6. *TYPHA ANGUSTIFOLIA* Community Type (n = 142)
   - 6.1 *TYPHA ANGUSTIFOLIA* / (MIX) subtype
   - 6.2a/b *TYPHA ANGUSTIFOLIA* (HIGH COVER / LOW COVER) / *SPARTINA CYNOSUROIDES* Subtype
7. *TYPHA* ×*GLAUCA* Community Type (N = 77)
   - 7.1 *TYPHA* ×*GLAUCA* / (MIX) Subtype
   - 7.2 *TYPHA* ×*GLAUCA* / *PHRAGMITES AUSTRALIS* (invasive) Subtype (transitional)
8. *PHRAGMITES AUSTRALIS* (invasive) Community Type (N = 241)
   - 8.1 *PHRAGMITES AUSTRALIS* (INVASIVE) / (MIX) Subtype
   - 8.2 *PHRAGMITES AUSTRALIS* (INVASIVE) / *TYPHA ANGUSTIFOLIA* Subtype (transitional)
   - 8.3a/b *PHRAGMITES AUSTRALIS* (INVASIVE) / *AGROSTIS STOLONIFERA* (spp. rich/ spp.
9. *SPARTINA ALTERNIFLORA* Community Type (N = 10)
   - 9.1 *SPARTINA ALTERNIFLORA* Subtype
   - 9.2 *SPARTINA ALTERNIFLORA* / *LILAEOPSIS CHINENSIS* Subtype
10. WRACK [~MIX] Community Type (N = 8)

A complete representation of the hierarchical cluster analysis of the Ragged Rock Creek brackish tidal marsh vegetation is presented in the Appendix, organized in a two-way plot-by-species table, including a dendrogram, and membership diagram of up to 100 clusters. A summary of the floristic differentiation among the 10 major plant community types reported at Ragged Rock Creek brackish is presented in a synoptic table depicting species' fidelity (indicator value), frequency (relative constancy) and dominance (average percent cover) (Table 2). The synoptic table is organized as a companion to the detailed descriptive account of the vegetation of Ragged Rock Creek brackish tidal marsh that follows. A brief description of the vegetation of Ragged Rock Creek brackish tidal marsh follows including: (1) a descriptive account of the 10 major classified plant community types (and subgroups representing common and mixed-types within the hierarchy) along with observations pertaining to ecology and geography; (2) a comparison of community types acknowledged from other investigations of Brackish tidal marsh wetlands in Connecticut, (3)another section regarding notable plant species such as underrepresented state-listed plants and non-native invasive plants, and (4) a vegetation map of Ragged Rock Creek brackish tidal marsh, and (5) an map accuracy assessment using a conservative contingency table approach.

Description of the major plant community types of Ragged Rock Creek brackish tidal marsh (with subtypes) (refer to synoptic table (Table 2)). (Plants that are discussed are the most important in defining the community types, being diagnostic or character species. Additional plant species, if not in the narrative, are listed in the synoptic table and in the appendix.)

Table 2. Synoptic table of Ragged Rock Creek tidal marsh vegetation types arranged by plant species' values of: Fidelity *(indicator value = iv)*, Frequency *(relative constancy = rc)*, and Average Cover *(percent cover = pc)*. Values are rounded to nearest interger; therefore 0 indicates a fractional percent, i.e., <1. Em dash --- indicates a negligent value or none. Bold type indicates significance at P < 0.05. Key to Community types: *S.p.= Spartina patens, P.v. = Panicum virgatum, J.g. = Juncus gerardii, Sch.a. = Schoenoplectus americanus, B.r. = Bolboschoenus robustus, T.a. = Typha angustifolia, T.xg. = Typha ×glauca, P.a. = Phragmites australis, S.a. = Spartina alterniflora.*

Group No.	*1*			*2*			*3*			*4*			*5*			*6*			*7*			*8*			*9*			*10*		
Community type	*S.P.*			*P.V.*			*J.G.*			*SCH.A.*			*B.R.*			*T.A.*			*T.XG.*			*S.A.*			*P.A.*			*WRACK*		
No.of plots	311			15			24			62			20			142			77			8			241			15		
Species/measure	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*
Spartina patens	**30**	**99**	**62**	5	40	5	1	21	4	**14**	**68**	**5**	1	15	7	2	25	3	0	8	4	---	---	---	1	18	2	3	33	2
Phragmites australis ssp. australis	3	31	15	1	20	0	5	42	11	6	45	13	1	20	3	1	16	1	5	42	19	0	13	0	**26**	**97**	**71**	4	40	4
Typha angustifolia	3	32	9	1	13	0	0	8	1	**11**	**60**	11	2	25	14	**28**	**97**	**74**	1	18	9	---	---	---	5	40	21	5	40	3
Solidago sempervirens	**13**	**58**	**2**	**14**	**60**	**0**	**17**	**67**	1	0	5	4	0	5	—	1	13	3	1	12	1	---	---	---	1	19	4	3	27	0
Bolboshoenus robustus	1	15	1	0	7	---	0	4	21	2	27	12	**32**	**100**	**80**	**10**	**6**	**6**	0	10	6	8	50	1	3	30	2	1	13	0
Schoenoplectus americanus	4	28	17	2	20	3	3	25	4	**44**	**100**	**64**	0	5	1	2	18	8	2	20	10	—	—	---	1	12	4	---	---	---
Agrostis stolonifera	**3**	**31**	**4**	**8**	**47**	**1**	**14**	**63**	**4**	1	15	2	4	35	16	2	24	13	0	5	10	2	25	5	1	17	18	3	27	0
Amaranthus cannibinus	1	10	0	---	---	---	1	13	0	0	7	0	**16**	**60**	**1**	**4**	**30**	**1**	1	17	0	**17**	**63**	**7**	2	19	0	0	7	---
Symphyotrichum novi-belgi	**10**	**33**	**0**	**14**	**40**	**0**	1	8	—	0	5	1	0	5	0	0	6	0	0	5	0	---	---	---	1	9	0	---	---	---
Juncus gerardii	**2**	**21**	**7**	**10**	**47**	**16**	**45**	**100**	**62**	0	7	1	0	5	0	0	9	3	0	5	5	1	13	7	1	11	9	0	7	0
Spartina cynosuroides	0	8	9	4	27	4	**12**	**46**	**3**	2	18	10	2	20	1	**5**	**30**	**10**	1	9	2	---	---	---	1	9	6	1	13	0
Schoenoplectus pungens	**7**	**29**	**4**	**10**	**33**	**0**	**10**	**33**	**2**	---	---	---	---	---	---	0	3	5	---	1	0	—	---	---	0	7	15	0	7	0
Persicaria punctata	1	12	0	2	13	—	0	4	---	3	19	1	1	10		2	17	1	0	7	2	1	13	0	2	17	2	0	7	
Eleocharis uniglumus	**16**	**32**	**9**	6	20	1	---	---		---	2	---	---	---	---	---	1	14	---	---		---	---	---	0	3	1	1	7	
Typha xglauca	0	5	8	0	7	0	0	4	---	1	8	7	---	---	---	0	3	15	**65**	**95**	**75**	---	---	---	0	3	2	1	13	17
Panicum virgatum	1	9	3	**68**	**100**	**71**	1	13	8		2	15	---	---	---	0	3	0	0	4	1	---	---	---	1	11	11	0	7	0
Atriplex prostrata/glabriuscula	1	10	0	1	7	---	1	8	0	1	7	0	1	10	0	1	9	0	---	---	---	---	---	---	1	10	0	2	13	0
Argentina anserina	1	10	1	6	27	0	**28**	**58**	4	0	3	0	0	5	---	0	4	0	0	3	0	---	—	---	0	5	1	0	7	---
Polygonuim ramosissimum	**5**	**17**	**0**	3	13	---	0	4	—	0	5	0	0	5		---	1	---	---	---	—		---	---	---	2	---	3	13	—
Symphyotrichum subulatum	**2**	**12**	**0**	1	7	---	3	13	0	2	11	0	0	5	0	0	4	0	---	---	---	—	---	---	1	5	0	1	7	---
Hibiscus moscheutos	0	4	7	1	7	—	---	---	---	---	---	---	---	---	—	0	5	1	**2**	**14**	**9**	---	---	---	1	9	5	**31**	**53**	---
Pluchea odorata var. succulenta	1	5	6	—	---	---	0	4	0	**4**	**15**	**0**	1	5	—	1	8	6	0	3	1	---	---	---	1	8	5	1	7	—
Spartina alterniflora	---	2	19	---	---	---	---	---	---	---	---	---	**6**	**30**	**3**	**1**	**9**	**10**	0	7	23	**66**	**100**	**80**	0	3	3	---	---	---
Triglochin maritima	**1**	**10**	**0**	**14**	**33**	**1**	**14**	**33**	**0**	—	2	0	---	---	---	-	---	---	---	---	---	---	---	---	—	1	---	—	---	---
Carex hormathodes	**5**	**12**	**0**	7	13	0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---
Sium suave	0	2	0	---	---	---	---	---	---	0	2	9	3	10	0	0	**3**	1	---	---	---	---	---	---	**2**	**8**	**0**	1	7	0
Iva frutescens	0	**4**	22	---	---	---	**13**	**21**	**10**	0	2	---	---	---	---	0	2	14	0	1	15	---	---	---	0	3	22	---	---	---
Persicaria sagittata	**1**	**6**	**2**	2	7	---	3	8	0	---	---	---	---	---	---	0	2	0	---	---	---	---	---	---	0	2	1	---	---	---
Ptillimnium capilaceum	0	3	0	---	---	---	---	---	---	0	2	---	1	5	---	---	1	0	---	---	---	---	---	---	1	5	—	**17**	**27**	---
Mikania scandens	---	**1**	0	---	---	---	---	---	—	---	---	---	---	---	—	---	---	---	---	---	---	---	---	---	**2**	**6**	**3**	**9**	**13**	---
WRACK	---	---	---	0	7	**4**	---	---	---	---	---	---	---	---	---	---	1	0	---	---	---	---	---	---	---	2	8	**91**	**100**	**87**
Bidens frondosa	---	0	—	1	7	---	---	---	---	---		---	0	5	—	---	1	---	---	---	---	---	---	---	0	3	---	**47**	**60**	**0**
Spartina pectinata	---	1	35	---	---	---	**11**	**17**	**2**	0	2	4	---	---		0	1	28	0	3	1	---	---	---	0	3	40		---	---
Calystegium sepium	0	1	7	---	---	---	—	—	—	---	---	---	---	---	---	---	—	---	---	---	---	---	---	---	**5**	**5**	**7**	—	—	---
Erechtites hieracifolius v. megalocarpus	0	1	—	---	---	---	1	4	0	---	---	---	---	---	---	---	---	---	0	3	2	---	---	---	0	3	12	7	13	---
Lythrum salicaria	0	1	0	---	---	---	---	---	---	---	---	---	---	---	---	---	—	—	---	---	---	---		---	**1**	**3**	**3**	**10**	**13**	**0**
Bolboschoenus maritimus ssp. paludosus	**1**	**3**	**4**	---	—	---	---	---	---	0	2	—	---	---	---	0	1	---	---	---	---	---	---	---	0	1	---	---	---	---
Distichlis spicata	0	1	0	---	---	---	**3**	**8**	**30**	1	5	7	---	---	---	---	1	0	---	---	---	---	---	---	---	0	---	2	7	—

Group No.	*1*			*2*			*3*			*4*			*5*			*6*			*7*			*8*			*9*			*10*		
Community type	*S.P.*			*P.V.*			*J.G.*			*SCH.A.*			*B.R.*			*T.A.*			*T.XG.*			*S.A.*			*P.A.*			*WRACK*		
No.of plots	311			15			24			62			20			142			77			8			241			15		
Species/measure	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*	*iv*	*rc*	*pc*
Amorpha fruticosa	---	---		---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	1	0	**38**	**40**	**0**
Crassula aquatica	---	1	---	3	7	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	**0**	**3**	**1**	3	7	0
Symphyotrichum tenuifolium	0	2	**1**	---	---	---	**3**	**8**	---	---	---	---	---	---	---	---	---	---	---	---	---	7	13	0	---	0	---		---	---
Cyperus odoratus	---	1	0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	1	0	**18**	**20**	**0**
Impatiens capensis	0	1	---	---	---	---	---	---	---	---	---	---	2	5	---	---	---	---	---	---	---	---	---	---	---	0	---	3	7	---
Juncus bufonius	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---		---	---	---	0	2	0	5	7	0
Schoenoplectus tabernaemontani	1	1	1	---		---	---	---	---	---	---	---	---	---	---	1	1	5	---	---	---	---	---	---	0	1	27	---	---	---
Bidens eatonii ?	---	0	---	---	---	---	1	4	0	---	---	---	---	---	---	---	1	---	0	1	0	---	---	---	---	0	---	**9**	**13**	---
Cyperus diandrus/filicinus	0	**1**	4	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	**1**	**2**	**9**	---	---	---
Phragmites australis ssp. americana	---	1	2	**17**	**20**	**1**	---	---	---	---	---	---	---	---	---	---	---	---	0	3	27			---	---	---	---	---	---	---
Bolboschoenus novae-angliae	---	---	---	---	---	---	2	4	0	0	2	---	---	---	---	1	2	53	---	---	---	---	---	---	---	0	48	---	---	---
Eleocharis parvula	---	0	5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	3	---	**7**	**13**	**20**	---	0	---	2	7	---
Ipomea sp	---	0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	1	---	6	7	---
Juncus accuminatus	0	0	10	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	2	14	---	---	---
Lilaeopsis chinensis	---	0	0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	4	31	**9**	**13**	**7**	---	0	0	---	---	---
Ludwigia palustris	---	1	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	1	0	5	7	---
Agalinis purpurea/paupercula	---	---	---		---	---	---	---	---	---	---	---	---	---	---		---	---	---	---	---	---	---	---	**2**	**2**	**0**	---	---	---
Galium trfiidum	0	0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	1		---	---	---
Persicaria longiseta	---	0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	0	---	---	---	11	13	2	---	0	---	---	---	---
Rumex crispus	---	0	---		---	---	---	---	---	---	---	---	---	---		---	---	---	---	---	---		---	---	---	1	---	**12**	**13**	---
Hierochloe odorata	---	---	---	---	---	---	7	---	---	---	---	---	---	---	---	0	1	---	---	---	---	---	---	---	---	0	0	---	---	---
Limosella australis	---	0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	**8**	13	---	---	0	---	2	7	0
Persicaria maculosa	1	1	0	---	---	---	---	---	---	---	---	---	---	---	---		---	---	---	---		---	---	---	0	0	0	---	---	---
Samolus valerandi ssp. parviflorus	---	---	---		---	---	---	---	---	---	---	---	---		---	---	---	---	1	1	---	---	---	---	1	1	0	---	---	---
Spergularia canadensis	---	1	6	---	---	---	---		---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Teucrium canadense	---	---	---	---	---	---	---		---	---	---	---	---	---	---	---	---	---	---	---	---	---	-	---	0	1	---	**6**	**7**	---
Cicuta bulbifera	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	0	**6**	**7**	---
Scutellaria lateriflora	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	-	---	---	0	0	---	---	---	---
Strophostyles helvula	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	0	**13**	**13**	---
Bidens connata ?	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	1	---	---	---	---	---	---	---	0	0	---	---	---	---
Peltandra virginiana	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	0	---	---	---	---
Persicaria arifolia	0	0	2	---	---	---	---	-	---	---	---	---	---	---	---	1	1	---	---	---	---	---	---	---	---	---	---	---	---	---
Solanum dulcamara	---	---	---	---	---	---	---	---	---	---	---	---	---	-	---	---	---	---	---	---	---	---	---	---	0	0	---	---	---	---
Toxicodendron radicans	---		---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	0	5	---	---	---
Baccharis halimifolia	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	**7**	**7**	---
Dichanthelium sp.	---	---	---	---	---	---	---	---	---		---	---	---		---	---	---	---	---	---	---	---	---	---	---	---	---	**7**	**7**	---
Ranunculus sceleriatis	0	0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Spartina xcaespitosa	0	0	6	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Verbena hastata	---	-	---	---	---	---	---	-	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0	0	0	---	---	---
Average No. of species	6			6			7			4			4			4			3			3			4			8		
Minimum No. of species	1			1			2			1			1			1			1			1			1			3		
Maximum No. of species	20			10			12			10			9			12			8			6			25			15		

The Vegetation of Ragged Rock Creek brackish tidal marsh

Community type names designated in Small caps font style to avoid confusion with individual taxa as species. Key to percent units: indicator value, *iv*; relative constancy, *rc*; and average percent cover, *pc.*)

1. *SPARTINA PATENS* CommunityType

The *SPARTINA PATENS (S.P.)* community type typically occurred in areas less flooded and better drained, such as in a "high marsh" position and levee. As a mapping unit, this community type was widespread throughout Ragged Rock becoming more extensive toward the southern reaches of the tidal marsh and closer to the Connecticut River estuary. The short stature of this vegetation properly defines this unit as a component of the Brackish tidal meadow. Meadows commonly occur in the panels between the dissecting creeks where more saline conditions sometimes occur. A total of 311 plots were used to describe the *S.P.* community type. The *S.p.* community type accounted for 28.02 hectares or 22 percent of the study area.

Spartina patens (30 *iv*,:99 *rc*, 62 *pc*) was the most characteristic plant, exhibiting the highest fidelity, frequency, and dominance. A sedge, *Eleocharis uniglumus,* also showed high fidelity and moderate frequency with low cover (16 *iv*, 32 *rc*, 9 *pc*), as did the forb, *Solidago sempervirens* (13 *iv*, 58 *rc*, 3 *pc*) - albeit, this forb was not as exclusive as *Eleocharis* was to the prevailing community type. Other significant plant associates with less fidelity, moderate frequency, and very low cover were: *Schoenoplectus americanus.* (7 *iv*, 29 *rc*, 4 *pc*), Sym.n-b. (10 *iv*, 33 *rc*, >1 *pc*), *Carex hormathoides* Horm. (5 *iv*, 11 *rc*, >1 *pc*), and *Polygonum ramocissimum.* (5 *iv*, 17 *rc*, >1 *pc*). *Agrostis stolonifera.* was significant but with a low fidelity, moderate frequency, and low cover (3 *iv*, 32 *rc*, 4 *pc*). Other significant plants in lesser amounts were *Juncus gerardii* (2 *iv*, 21 *rc*, 7 *pc*), *Symphyotrichum novi-belgi* (2 *iv*, 12 *rc*, <1 *pc*), *Bolboschoenus maritimus* (1 *iv*, 3 *rc*, 4 *pc*), *Triglochin maritima* (1 *iv*, 10 *rc*, <1 *pc*), *Persicaria sagitata* (1 *iv*, 6 *rc*, 2 *pc*).

Several other species that were not sigificantly indicative (low fidelity), yet common enough with moderate cover were: *Typha angustifolia* (4 *iv*, 32 *rc*, 17 *pc*), *Phragmites australis* (invasive non-native)(3 *iv*, 31 *rc*, 15 *pc*), and *Schoenoplectus americanus* (4 *iv*, 28 *rc*, 17 *pc*). Also, *Iva frutescens* (4 *iv*, 4 *rc*, 21 *pc*) was neither indicative or common but it exhibited moderately high cover when present. Not surprisingly, those same species that were common and of moderate cover were recognized at a higher cluster level in the hierarchical classification as codominants in the subtypes:

1.1 *SPARTINA PATENS* / (MIX) Subtype
1.2 *SPARTINA PATENS / ELEOCHARIS UNIGLUMUS* Subtype
1.3 *SPARTINA PATENS / TYPHA ANGUSTIFOLIA* Subtype (transitional)
1.4 *SPARTINA PATENS / PHRAGMITES AUSTRALIS* (invasive) Subtype (transitional)
1.5 *SPARTINA PATENS / SCHEONOPLECTUS AMERICANUS* Subtype (transitional)
1.6 *IVA FRUTESCENS* / (S.P. - MIX) Subtype

Three of the subtypes, 1.3, 1.4, and 1.5, associated with, *Typha angustifolia*, invasive *Phagmites*, and *Scheonoplectus americanus* (respectively) as co-dominants, were considered to be more transitional in type, whereas subtypes 1.1, 1.2, and 1.6 were generally considered a mix, yet not necessarily a transitional type. A possible exception was 1.1 *Spartina patens* which may also occur in pure stands. The spatial extent of these subtypes extent varies throughout the marsh especially transitional types that coincide with the identity of the neighboring type. The last subtype designated *IVA FRUTESCENS* / (*S.P.*- MIX) is common to most levees.

Other notable plants found growing on the exposed levees of the Connecticut River in the *S.P.* type (and just outside the *J.G.* type) were the state-listed *Spergula canadensis* and *Juncus bufonius*.

2. *PANICUM VIRGATUM* Community Type

The *PANICUM VIRGATUM (P.V.)* community type occurred in areas less flooded and better drained, such as in a "high marsh" position and levee in meadow habitats, similar in habitat and geography with the *S.P.* community type with which the *P.V.* community type shared. A total of 15 plots were sampled to describe the *P.V.* community type. The *P.V.* community type covered 14.11 hectares or 11 percent of the study area.

Panicum virgatum was the characteristic plant with high fidelity, always present, and dominant (68 *iv*, 100 *rc*, 71 *pc*), (indicator value, relative constancy,and average percent cover, respectively). While most strongly concentrated here, *Panicum virgatum* was poorly represented in other community-types. Of interest was another highly associated plant, the less common, and infrequent native *Phragmites australis* var. *americana* (17 *iv*, 20 *rc*, 1 *pc*). Other significant plants included: *Symphyotrichum novi-belgi* (14 *iv*, 40 *rc*, <1 *pc*), *Triglochin maritimum* (14 *iv*, 33 *rc*, <1 *pc*), *Solidago sempervirens* (14 *iv*, 60 *rc*, <1 *pc*), *Schoenoplectus pungens* (10 *iv*, 46 *rc*, <1 *pc*), *Agrostis stolonifera* (8 *iv*, 47 *rc*, <1 *pc*). The strongest associated plant overall was *Juncus gerardii* (10 *iv*, 47 *rc*, 16 *pc*).

No further subgroups were recognized at the 25 cluster level.

3. *JUNCUS GERARDII* Community Type

The *JUNCUS GERARDII (J.G.)* community type was encountered most frequently on larger more exposed levees flanking the Connecticut River and to a lesser extent upon the better developed levees of Ragged Rock Creek. A total of 24 plots were recorded to describe the *J.G.* community type. As a mapping unit, the *J.G.* type was difficult to spatially resolve on the map, it was mostly incorporated into the *S.P.* mapping unit.

Juncus gerardii (45 *iv*, 100 *rc*, 62 *pc*) was characteristic being most typical, very frequent and dominant. *Argentina anserina* (28 *iv*, 58 *rc*, 4 *pc*) was an important associate on the largest levees. Other significant plants included *Solidago sempervirens* (17 *iv*, 67 *rc*, >1 *pc*), *Agrostis stolonifera* (14 *iv*, 63 *rc*, 4 *pc*), *Spartina cynosuroides* (12 *iv*, 46 *rc*, 4 *pc*) and *Spartina pectinata*

(10 *iv*, 17 *rc*, 2 *pc*) (to a lesser extent), and *Iva frutescens* (13 *iv*, 21 *rc*, 10 *pc*). Also present was *Triglochin maritima* (14 *iv*, 33 *rc*, >1 *pc*) and *Schoenoplectus pungens* (9 *iv*, 33 *rc*, 2 *pc*). Other important plants found growing on the exposed levee of the Connecticut River just outside the *J.G.* type were *Spergularia canadensis, Juncus bufonius*, and *Tillea aquatica.*

The major *J.G.* type was subdived into three subtypes at the 25 cluster level:

3.1 *JUNCUS GERARDII* / (FORB MIX) Subtype
3.2 *JUNCUS GERARDII* / *ARGENTINA ANSERINA* Subtype
3.3 *JUNCUS GERARDII* / *PHRAGMITES AUSTRALIS* (invasive) Subtype (transitional)

4. *SCHOENOPLECTUS AMERICANUS* Community Type

The *SCHOENOPLECTUS AMERICANUS (SCH.A.)* community type was widespread throughout the marsh yet more frequent toward the central and southern reaches. This community type was often occurred in slightly less saline sites but still coinciding with the other brackish meadow types, *S.P.* type, and *P.V.* type. A total of 62 plots were recorded to describe the *SCH.A.* community type. The *SCH.A.* type occupied approximately 19.61 hectares or 15 percent of the study area.

Schoenoplectus americanus (= S. olynei) (44 *iv*, 100 *rc*, 65 *pc*) typified this type with high frequency and dominance. Other significant species with high frequency and moderate cover included *Spartina patens* (14 *iv*, 68 *rc*, 5 *pc*) and *Typha angustifolia* (11 *iv*, 60 *rc*, 12 *pc*). *Pluchea odorata* (4 iv, 15 *rc*, <1 *pc*) was frequently associated while not restricted to this type.

The major *SCH. A.* type was subdivided in two subtypes at the 25 cluster level:

4.1 *SCHOENOPLECTUS AMERICANUS* / (MIX) Subtype
4.2 *SCHOENOPLECTUS AMERICANUS* / *TYPHA ANGUSTIFOLIA (± PHRAGMITES AUSTRALIS (INVASIVE))* Subtype (transitional)

(See also:
1.5 *SPARTINA PATENS* / *SCHEONOPLECTUS AMERICANUS* Subtype (transitional)

5. *BOLBOSCHOENUS ROBUSTUS* Community Type

The *BOLBOSCHOENUS ROBUSTUS (B.r.)* community type occurred mainly in slightly low-lying areas in the marsh including aggrading ditches or wide sloping stream banks behind *Spartina alterniflora.* Several large concentrations occur in the central and back areas of the tidal marsh. A total of 20 plots were sampled to describe the *B.R.* community type. The *B.R.* type occupied approximately 14.21 hectares or 11 percent of the study area.

Often forming dense stands achieving high dominance, *Bulboschoenus robustus* (32 *iv*, 100 *rc*, 80 *pc*) was the plant species of greatest indicator value. Other characteristic plants

associated with this type were *Amaranthus cannibinus* (16 *iv*, 60 *rc*, <1 *pc*) and *Spartina alterniflora* (6 *iv*, 30 *rc*, 3 *pc*).

No further subgroups were recognized at the 25 cluster level.

6. *TYPHA ANGUSTIFOLIA* Community Type

The *TYPHA ANGUSTIFOLIA (T.A.)* community type was widespread throughout the tidal wetland and it was the most extensive in total area and often appeared as the matrix often surrounding the brackish "meadow" community types. The *T.A.* type also occupied sites as wet as the *B.R.* type but was not quite as restricted there. The tall community types dominated by *Tyha* sp. and/or *Phragmites asutralis* are generally refered to in brackish tidal habitats as "reed" marshes. A total of 142 plots were recorded to describe the *T.A.* community type. The *T.A.* type occupied approximately 17.38 hectares or 14 percent of the study area.

Typha angustifolia (29 *iv*, 97 *rc*, 74 *pc*) was the signature plant dominating this community type, albeit, not limited strictly to this type. Other significant plants included *Bolboschoenus robustus* (10*iv*, 60*rc*,<1*pc*), *Spartina cynosuroides* (4 *iv*, 30 *rc*,<1*pc*) as well as *Amaranthus cannibinus* (4 *iv*, 30 *rc*, <1 *pc*) and *Spartina alterniflora* (0.6 *iv*, 9 *rc*, 10 *pc*).

The major *T. A.* community type was subdivided into 2 [3 originally] subtypes here, but originally three subtypes at the 25 cluster level:

6.1 *TYPHA ANGUSTIFOLIA* / (MIX) subtype

6.2a/b *TYPHA ANGUSTIFOLIA* (HIGH COVER / LOW COVER) / *SPARTINA CYNOSUROIDES* Subtype (This subtype is a combination of two very compositionally similar communities subdivided in the hierarchical classification primarily on the basis of different extremes in *Typha* cover, hence combined here for practical reasons.)

(See also:

1.3 *SPARTINA PATENS* / *TYPHA ANGUSTIFOLIA* Subtype (transitional)

4.2 *SCHOENOPLECTUS AMERICANUS* / *TYPHA ANGUSTIFOLIA* (± *PHRAGMITES AUSTRALIS* (INVASIVE)) Subtype (transitional)

8.2 *PHRAGMITES AUSTRALIS* (INVASIVE) / *TYPHA ANGUSTIFOLIA* Subtype (transition)

7. *TYPHA* ×*GLAUCA* Community Type

The *TYPHA X GLAUCA (T.XG.)*community type occurred throughout the marsh with larger concentrations in the backmarsh reaches along the uplands and behind the northern levee in the un-ditched portion of the marsh. The *T.XG.* type was found in sites similar as the *T.A.* community, though several of the backmarsh sites appeared slightly fresher and slightly wetter. A total of 77 sites were used to describe the *T.xg.* type. The *T.xg.* sites covered approximately 6.80 hectares or 5 percent of the marsh.

Typha ×glauca (65 *iv*, 95 *rc*, 75 *pc*), the hybrid of *T. angustifolia* and *T. latifolia*, was the signature dominant species of this community type. *Hibiscus moscheutos* (2 *iv*, 14 *rc*, 9 *pc*) was another characteristic plant. The *T.XG.* community type was more species poor than its counterpart, the *T.A.* community type.

The major *T.xg.* community type was subdivided into two subtypes:

7.1 *TYPHA ×GLAUCA* / (MIX) Subtype
7.2 *TYPHA ×GLAUCA / PHRAGMITES AUSTRALIS* (invasive) Subtype (transitional)

Although both species of *Typha* did co-occur, their coincidence at higher cluster levels remained insufficient to create a joint community type at Ragged Rock Creek brackish tidal marsh.

8. *PHRAGMITES AUSTRALIS* (invasive) Community Type

The *PHRAGMITES AUSTRALIS (P.A.)* (invasive) community type was widespread across the marsh. Patches of this community type were better developed along the northern and southern reaches of the marsh particularly along upland railroad verges and abandoned trolley crossing. A total of 241 plots were used to describe the *P.A.* community type. The *P.a.* community type accounts for 27.18 hectares or 21 percent of the study area.

Phragmite australis (26 *iv*, 97 *rc*, 71 *pc*) was the defining species for this community type. This community type had the greatest variety of associated species (25 total spp). Several significant species present at low frequency and low cover include *Calystegium sepium* (5 *iv*, 5 *rc*, 7 *pc*), *Mikania scandens* (2 *iv*, 6 *rc*, 3 *pc*), *Lythrum salicaria* (<1 *iv*, 3 *rc*, 3 *pc*), *Cyperus diandrus/filicinus* (1 *iv*, 2 *rc*, 9 *pc*), *Agalinis purpurea/paupercula* (2 *iv*, 2 *rc*, <1 *pc*), and *Sium suave* (2 *iv*, 8 *rc*, <1 *pc*).

Several more common and widespread species were present but not significant based on fidelity, but coexisted at higher moderate relative constancies and low percent cover. Not surprisingly, many of those species were recognized at a higher cluster level in the hierarchical classification as co-dominants in the subtypes (Table x). These plant species included *Spartina patens* (1 *iv*, 18 *rc*, 2 *pc*), *Typha angustifolia* (5 *iv*, 97 *rc*, 71 *pc*), and *Bolboschoenus robustus* (3 *iv*, 30 *rc*, 2 *pc*).

The major *P.A.* community type was subdivided into 3[4 originally] subtypes:

8.1 *PHRAGMITES AUSTRALIS* (INVASIVE) / (MIX) Subtype
8.2 *PHRAGMITES AUSTRALIS* (INVASIVE) / *TYPHA ANGUSTIFOLIA* Subtype (transitional)
8.3a/b *PHRAGMITES AUSTRALIS* (INVASIVE) / *AGROSTIS STOLONIFERA* (spp. rich/ spp. poor) Subtype (transitional). (This subtype is a combination of two similar subtypes originally subdivided in the hierarchical classification that differed in the richness/poorness of the accompanying plants; hence, for practical reasons, they were combined here.)

(see also:

1.4 *SPARTINA PATENS / PHRAGMITES AUSTRALIS* (invasive) Subtype (transitional)
3.3 *JUNCUS GERARDII / PHRAGMITES AUSTRALIS* (invasive) Subtype (transitional)
4.2 *SCHOENOPLECTUS AMERICANUS / TYPHA ANGUSTIFOLIA (± PHRAGMITES AUSTRALIS (INVASIVE))* Subtype (transitional)
7.2 *TYPHA ×GLAUCA / PHRAGMITES AUSTRALIS* (invasive) subtype (transitional)

9. *SPARTINA ALTERNIFLORA* Community Type

The *SPARTINA ALTERNIFLORA (S.A.)* community type was restricted in distribution to stream banks of varying width and slope, as well as the margins of tidally active ditches. A total of 10 plots were surveyed to describe this plant community type. The areal extent of this type was not estimated.

The signature plant, *Spartina alterniflora* (66 *iv*, 100 *rc*, 80 *pc*) occured with high fidelity, frequency and dominance. This community type was species poor (6 total spp.). Other assocated plants were *Amaranthus cannibinus* (17 *iv*, 63 *rc*, 7 *pc*), *Elecharis parvula* (7 *iv*, 13 *rc*, 20 *pc*). Tow state-listed conservation species were *Lilaeopsis chinensis* (9 *iv*, 13 *rc*, 7 *pc*), and *Limosella australis* (8 *iv*, 13 *rc*, <1 *pc*).

The major *S.A.* community type was subdivided into 2 subtypes:

9.1 *SPARTINA ALTERNIFLORA* Subtype
9.2 *SPARTINA ALTERNIFLORA / LILAEOPSIS CHINENSIS* Subtype

10. WRACK [~MIX] Community Type

The WRACK [MIX] community type was distributed mostly along the top of the large levee of the Connecticut River and occasionally in backwater areas at a position of extreme high water. The spatial extent and density of the WRACK accumulation was quite variable and changing presumably with seasonal flooding and other high water events. A total number of 8 plots used to describe the WRACK [MIX] type. The areal extent of WRACK was not estimated.

The species composition of the WRACK [mix] type was variable and always at a very low cover percentage. Besides an abundance of WRACK litter other species included *Bidens frondosa* (47 *iv*, 60 *rc*, <1 *pc*), *Amorpha fruticosa* - seedlings (38 *iv*, 40 *rc*, <1 *pc*), *Hibiscus moschuetos* –seedlings (31 *iv*, 53 *rc*, <1 *pc*), *Ptilimnium capillaceum* (17 *iv*, 27 *rc*, <1 *pc*), Cyoerus odoratus (18 *iv*, 20 *rc*, <1 *pc*), *Strophostyles helvula* (13 *iv*, 13 *rc*, <1 *pc*), *Rumex crispus* (12 *iv*, 13 *rc*, <1 *pc*), *Lythrum salicaria* (10 *iv*, 13 *rc*, <1 *pc*), *Bidens eatonii* (9 *iv*, 13 *rc*, <1 *pc*), and a few others (table x).

A comparison with other studies of brackish tidal wetland vegetations

Table 3. Cross-reference of several accounts of brackish marsh community types compared to Ragged Rock Creek marsh

Nichol's (1920)	***Metzler & Rosza (1982, 1989)***	***Barrett, N. (1989)***	***Metzler and J. Barrett (2006)***	***NatureServe's Associations***	***Rosza (pers. comm 2004)***	***Ragged Rock Creek 2006 –this study***
Ruppia maritima - Potamogeton spp. (sub- & lowerlittoral)	*Ruppia maritima - Zannichellia palustris - Potamogeton spp* (aquatic bed)	*Ruppia maritima - Potamogeton spp.* (aquatic bed)	*Ruppia maritima & Zannichellia palustris* tidally-flooded hydromorph.	*Stuckenia pectinata - Potamogeton perfoliatus - (Zannichellia palustris)* Tidal Herb. Vegetation	Muddy bottoms, Flats, and shores not mentioned - focus on communities where invasive *Phragmites* is at issue	Not sampled Submerged Aquatic Vegetation present in creeks and cove
Lophotocarpus spongiosus - Liliaopsis lineata - Ranunculus cymbalaria (muddy shores & flats)	*Sagittaria montevidensis - Sagittaria subulata* (flats)	*Sagittaria montevidensis - Amaranthus cannibinus* (shorebanks & flats)	*Sagittaria subulata - Zannichellia palustris* tidal forb vegetation	*Sagittaria subulata - Limosella australis* Tidal Herb. Vegetation		Not present at study site
Spartina glabra – Acnida cannibinus (midlittoral)	*Spartina alterniflora Amaranthus cannibinus* (midtidal)		*Amaranthus cannabinus* tidal forb vegetation	*Amaranthus cannabinus* Tidal Herb. Vegetation		
Spartina glabra (midlittoral marsh)	*Spartina alterniflora* (midtidal)	*Spartina alterniflora* (mid-tidal "low" marsh)	*Spartina alterniflora* Tidal grasslands		"low marsh zone of *Spartina alterniflora*" and may support *Limosella subulata* and *Lilaeopsis chinensis*	*Spartina alterniflora* (mid-tidal "low" marsh")
	Spartina alterniflora - admixture (midtidal)	*Spartina alterniflora - Lilaeopsis chinensis* (variant)	*Spartina alterniflora - Lilaeopsis chinensis* Tidal grasslands	*Spartina alterniflora - Lilaeopsis chinensis* Tidal Herb. Vegetation		*Spartina alterniflora - Lilaeopsis chinensis* (variant)
Scirpus americanus (midlittoral)	*Scirpus pungens* (midtidal border)	*Scirpus pungens* (mid-tidal)	*Schoenoplectus pungens - Sagittaria spp.)* Tidal grasslands	*Schoenoplectus pungens* Tidal Herb. Vegetation		*Schoenoplectuc pungens – Sch. Americanus (S. olneyii) Bolboschoenus robustus. B. novae-angliae* (includes wetter marshes)
Scirpus americanus, S. Olneyi, S. campestris, S. robustus (wetter marshes)		*Scirpus robustus* (variant) *S.cylindricus (= S. novae-angliae)* (variant)	*Schoenoplectus pungens - Sch. robustus (- Sch. Novae-angliae)* Tidal grasslands		*Scirpus*-dominated communities	
Spartina patens - Distichlis spicata - Juncus Gerardi - Agrostis stolonifera (upperlittoral meadow)		*Spartina patens* (meadow variant)	*Spartina patens - Distichlis spicata (Juncus gerardi)* tidal grasslands	*Spartina patens - Distichlis spicata (Juncus gerardii)* tidal grasslands		*Spartina patens Eleocharis uniglumis (E. rostellata)* (meadow variant)
					Spartina patens - Juncus gerardii meadow with *Agrostis stolonifera* a "local dominant"	*Juncus gerardiil* mix (meadow variant)
Spartina patens - Agrostis alba (upperlittoral meadow)		*Spartina patens - Agrostis stolonifera* (meadow)	*Spartina patens - Agrostis stolonifera* tidal grasslands	*Spartina patens - Agrostis stolonifera* Tidal Herb. Vegetation		*Agrostis stolonifera (Spartina patens)* (meadow variant)
			Panicum virgatum tidal grasslands	*Panicum virgatum* tidal grasslands	Not discussed	*Panicum virgatum* (meadow variant)
		S. patens –Agrostis s. Transitions to Typha a., Phragmites, S. americanus			*Typha angustifolia* "low stem density" marsh/meadow *Phragmites* [invasion in progress	*S. patens –Agrostis s. Transitions to Typha spp, Phragmites, S. americanus,* + other transitions
Typha angustifolia (upperlittoral marsh)	*Typha angustifolia* (tall reed zone) [in part]	*Typha angustifolia* (brackish tidal marsh typical)	*Typha angustifolia - Hibiscus moscheutos* tidally-flooded [in part]	*Typha angustifolia - Hibiscus moscheutos* Tidal Herb. Vegetation	*Typha angustifolia* "dense" growth form [in part]	*Typha angustifolia* (brackish tidal marsh typical)
		Typha angustifolia - Spartina cynosuroides (variant - levee)	*Typha angustifolia - Hibiscus moscheutos* tidally-flooded [in part]	*Spartina cynosuroides* Tidal Herb. Vegetation	*Spartina cynosuroides*-dominated levees [and, in part, and *Typha xglauca* "diffuse growth form" stand	*Typha angustifolia - Spartina cynosuroides* (variant - levee)
					Typha ×glauca "diffuse growth form"	*Typha ×glauca* (brackish tidal marsh)
Phragmites communis (upperlittoral marsh)	*Phragmites australis* - admixture (tall reed zone)	*Phragmites australis* (variant – marsh & levee)	*Phragmites australis* dominated *Typha angustifolia - Hibiscus moscheutos* tidally-flooded [in part]	*Phragmites australis* Tidal Herb. Vegetation	*Phragmites* dominated marsh [in part]	*Phragmites australis* (Brackish tidal marsh)
Shrubs & extension of upper littoral [in part] (supralittoral)	Supralittoral - indicated but not described	*Phragmites australis & Iva frutescens* [in part] (levee & upper border)	*Iva frutescens* Tidal shrubland	*Iva frutescens* Tidal shrubland	Not discussed	*Iva frutescens* /Mix (levee & upper border)

To put this study in context with other similar research on the vegetation of brackish tidal wetlands, a comparative account is presented in Table 3.

Plant species of conservation interest – invasive, non-native plant species and state-listed or otherwise important plant species for conservation

Non-native and/or invasive plants

In the course of this study, we documented within our Ragged Rock Creek study area occurrences of at least fourteen plant taxa recognized as: non-native (6 taxa), widespread, invasive and banned (5 taxa), or potentially invasive and banned (3 taxa) according to Mehrhoff, L. J., K. J. Metzler, and E. E. Corrigan, "Non-native invasive and potentially invasive vascular plants in Connecticut" a 4-page pamphlet, printed in 2003 by the. Center for Conservation and Biodiversity, University of Connecticut, Storrs. These plant taxa are presented in Table 4. The term "banned " means it is illegal in Connecticut to import, move, sell, purchase, cultivate, or distribute this species, per Connecticut Public Acts 02-136 and 04-203.

Plant species of conservation concern

In the course of this study, we documented within our Ragged Rock Creek study area occurrences of at least eight, possibly ten, plant taxa of recognized (scientifically and/or legally) conservation concern. These plant taxa are presented in Table 5. Nine of these taxa are currently legally listed under Connecticut law (Connecticut General Statutes (CGS) Section 26-303). as either "Endangered", "Threatened", or "Special Concern" (CT-DEP 2004+). One taxon, *Phragmites australis* ssp. *americanus*, is currently neither State-listed nor proposed for State-listing in Connecticut, but it is ranked as, at rarest, an S3 in all other eastern states/provinces in which it is known to occur (NatureServe 2009), it is currently known from only 4 sites in Connecticut (Zyko pers. comm., Rosza pers. comm., Metzler pers. comm.), and is currently considered a conservation priority by many resource managers throughout North America.

Table 4. Known or suspected invasive and/or non-native plants documented at Ragged Rock Creek in 2006 (14 taxa).

Scientific Name	*Common Name*	*ID confidence*	*Invasive Status in CT*[1,2]	*Habitat affinity*	*Comments*
Agrostis stolonifera L.	Creeping Bentgrass	definite	Not listed	Frequently a dominant ground cover on levees of interior creeks, and a frequent non-dominant associate in the *S.P.* community	Often considered non-native in North America, some authorities believe it could be native, at least northward (Haines 2009)
Amorpha fruticosa L.	Flase Indigo	definite	PI/banned	Upper beaches and shoreline/forest edge, dune scrub, and behind-the-dune swales.	
Callitriche stagnalis Scop.	Pond Water-Starwort	definite	PI/banned	Observed occasionally on northernmost stretch of River levee in relatively diffuse expression of *P.A.* community	
Celastrus orbiculatus Thunb.	Asiatic Bittersweet	definite	WI/banned	*P.A.* community, mostly near upland boundaries, occasionally in marsh interior	Syn: *Celastrus orbiculata* Thunb.
Iris pseudacorus L.	Yellow Iris	sp.?	WI/banned	Recorded rarely in *S.P.* community, on or just behind the river levee	
Lapsana communis L.	Nipplewort	definite	Not listed	Occasional in WRACK Community	
Lythrum salicaria L.	Purple Loosestrife	definite	WI/banned	Recorded & observed on or near the river levee, most abundantly at near the north end of the river levee, in several communities. Most frequently recorded in *P.A.* community and the S.P. community. Also in *T.A.*, *T.XG.* and WRACK communities.	Relatively low and diffuse at its most abundant, it probably is suppressed by higher salinities later in the summer.
Microstegium vimineum (Trin.) A. Camus	Japanese Stilt Grass	definite	WI/banned	Rare, in *P.A.* community on the northern river levee	
Polygonum caespitosum Blume	Bristle Knotweed	sp.?	PI/banned	Northern river levee, in *P.A.* community and the *S.P.* community	syn: *Persicaria longiseta* (Bruijn) Kitagawa

Table 4. Known or suspected invasive and/or non-native plants documented at Ragged Rock Creek in 2006 (14 taxa).

Scientific Name	*Common Name*	*ID confidence*	*Invasive Status in CT*[1,2]	*Habitat affinity*	*Comments*
Phragmites australis (Cav.) Trin.	Common Reed	definite	WI/banned	Widespread across the entire study area. Patches most often bordering ditches and smaller creeks, and at the back of and just behind the river levee, occasionally occupying the entire levee up to the levee front.	syn:*Phragmites australis* (Cav.) Trin. *ex* Steud. ssp. *australis*
Persicaria maculosa S.F. Gray	Lady's-thumb Smartweed	sp.?	Not listed	Ocassionally recorded on the northern river levee in the *P.A.* community, and in the interior marsh in the *S.P.* community	
Rumex crispus L. ssp. *crispus*	Curly Dock	sp.?	Not listed	Occuring rarely and in small numbers, but widely throughout the marsh in several communities, but most frequently in the WRACK Community	
Typha angustifolia L.	Narrow-leaved Cat-tail	definite	Not listed	Widespread over entire marsh, often a dominant species in large patches	The view that this species is actually not native to the U.S. is gaining acceptance (Stuckey & Salamon 1987; NRCS PLANTS database 2009; Haines 2009). Should it then be viewed as an invasive, given its abundance and habitat?
Typha ×*glauca* Godr.	Hybrid of Broad-leaved and Narrow-leaved Cat-tail	definite	Not listed	Widespread and often a near-monotypic dominant in large patches, but most abundant in the back marsh	If one of the parent taxa of this species is non-native, and its habit (usually taller and denser than *T. angustifolia*), should it also be viewed as an invasive, given its abundance and habitat?

Table 4. Known or suspected invasive and/or non-native plants documented at Ragged Rock Creek in 2006 (14 taxa).

Scientific Name	*Common Name*	*ID confidence*	*Invasive Status in CT*[1,2]	*Habitat affinity*	*Comments*

TABLE NOTES:

[1]Invasives status abbreviations: WI = Widespread and Invasive; PI = Potentially Invasive (from Mehrhoff, L. J., K. J. Metzler, and E. E. Corrigan. 2003. Non-native invasive and potentially invasive vascular plants in Connecticut. Center for Conservation and Biodiversity, University of Connecticut, Storrs. 4-page pamphlet.

[2]"banned " means it is illegal in Connecticut to import, move, sell, purchase, cultivate, or distribute this species, per Connecticut Public Acts 02-136 and 04-203

Table 5. Plants of recognized conservation concern documented at Ragged Rock Creek during this study.

Taxon[1]	*State/global conservation rank*[2]	*State legal status*	*Name as listed in State legal list*	*Other synonyms*	*Comments*
Atriplex glabriuscula Edmondston	SU/G4	Special Concern	*Atriplex glabriuscula*		Identification uncertain
Bidens eatonii Fernald	S1/G2G3	Threatened	*Bidens eatonii*		Identification uncertain: specimens appear intermediate between *B. eatonii* and *B. connata*, and thus may be the hybrid *Bidens ×multiceps*
Bolboschoenus maritimus (L.) Palla ssp. *paludosus* (A. Nels.) T. Koyama	S2S3/G5	Special Concern	*Scirpus paludosus* var. *atlanticus*	*Schoenoplectus maritimus* (L.) Lye	
Bolboschoenus novae-angliae (Britt.) S.G. Smith	S3/G5	Special Concern	*Scirpus cylindricus*	*Schoenoplectus novae-angliae* (Britton) M.T. Strong	
Crassula aquatica (L.) Schoenl.	S1/G5	Endangered	*Crassula aquatica*	*Tillaea aquatica* L.	
Lilaeopsis chinensis (L.) Kuntze	S3/G5	Special Concern	*Lilaeopsis chinensis*		
Limosella australis R. Br.	S3/G4G5	Special Concern	*Limosella subulata*		
Phragmites australis (Cav.) Trin. *ex* Steud. ssp. *americanus* Saltonstall, P.M. Peterson, & Soreng	SH/G5T4	none	NA		
Ranunculus sceleratus L.	S3S4/G5	Special Concern	*Ranunculus sceleratus*		Proposed to be delisted in Connecticut in 2009
Spergularia canadensis (Pers.) G. Don	S1/G5	Threatened	*Spergularia canadensis*		

Table Notes:
[1]Taxonomy follows Flora of North America Vol. 23 for Cyperaceae, Haines draft Flora Novae Angliae for other taxa, if different
[2]State conservation ranks come from the CT-DEP Natural Diversity Data Base 8/24/09. Global conservation rank come sfrom Natureserve, accessed 8/26/09

Plant species of conservation concern- Species accounts

Bidens eatonii

Bidens eatonii Fernald [ASTERACEAE] (common names: Eaton's Beggarticks, or Eaton's Beggar-tick), is an annual, small to medium-height forb that is ranked by Naturserve (Natureserve 2009) as G2G3, i.e., on the borderline between a "globally imperiled" and "globally vulnerable" taxon. It is a northeastern coastal endemic and the only one of plants we documented at Ragged Rock Creek not considered globally secure. We observed and collected plants that arguably be assigned to this taxon at Ragged Rock Creek in 2006. However, all of our specimens have characters intermediate between *Bidens eatonii* and the similar, common species *Bidens connata.* Thus we suspect that these plants are the hybrid of those two species, *Bidens ×multiceps* Fassett, which is reported from at least one other estuary in New England (Haines 2009). An alternative interpretation is that these Ragged Rock Creek plants are within the range of variability (perhaps not yet fully documented) of *Bidens eatonii*, and that these putative *Bidens ×multiceps* plants are simply *Bidens eatonii* (they do appear to be fertile, based on the appearance of the achenes). Late in the growing season, we observed "good" examples of *Bidens connata* at Ragged Rock Creek, but no plants that we could confidently assign to "good" *Bidens eatonii.* Most of our plots were sampled while plants were still too immature to distinguish between *Bidens eatonii*, *B. connata*, and B. *×multiceps.* We recorded these plants as either *Bidens connata* or "*Bidens eatonii*?", whichever we judged most likely based on vegetative characters. However, if *Bidens ×multiceps* occurs at Ragged Rock Creek, it is unlikely that it could be distinguished with confidence from either parent taxa, based on vegetative characters alone. Because the conservation significance of *Bidens eatonii*, we returned in the fall, to most of the plots where we had recorded either putative *Bidens connata* or putative *Bidens eatonii*, so we could make more definite determinations based on mature material. However, in most of these revisited plots we could not relocate the plants. A fall flood and several very high spring tides had redistributed wrack and generally beaten up the lower vegetation. During the fall revisit we did find both "good" *Bidens connata* and the suspected hybrid *Bidens ×multiceps* on wrack on the southern river levee, near plots where we recorded "*Bidens eatonii*?" earlier, and near plots in the in the backmarsh, where we had recorded either Bidens connata or "Bidens eatonii?" earlier.

Thus, we have concluded that in most plots where we recorded "*Bidens eatonii*?" or *Bidens connata*, we cannot say with confidence which of the three taxa, *B. eatonii*, *B. connata*, or *B. ×multiceps*, were actually present in the plots, and that any or all of the taxa are possibilities. Immature plants resembling both and *Bidens eatonii* or *B. connata* were recorded in or adjacent to 18 plots, typically in very small numbers. The majority of these plots were just behind or on the river levee in the *P.A.* community, WRACK, and *J.G.* community (in order of decreasing frequency). A second area of more frequent occurrence of *Bidens connata/eatonii/×multiceps* was the southwestern backmarsh, near upland borders and on creek banks near the creek heads, where the associated community types were the *PHRAGMITES AUSTRALIS* (invasive) Community, *TYPHA ×GLAUCA* Community, and *SPARTINA PATENS* Community (*SPARTINA PATENS / TYPHA ANGUSTIFOLIA* Subtype). *Bidens connata/eatonii/×multiceps* was recorded rarely between the river levee and the backmarsh in plots classified as the *TYPHA ANGUSTIFOLIA* Community, once in the interior of the unditched portion of the marsh north of the mouth of Ragged Rock Creek and

once close the shore of embayment at the south end of the marsh, and putative *Bidens ×multiceps* was observed and collected once in the *SPARTINA PATENS* Community, also in the interior of the unditched portion of the marsh north of the mouth of Ragged Rock Creek, near a plot in the *TYPHA ANGUSTIFOLIA* Community where "Bidens eatonii?" was earlier recorded but not found later. Finally, we found both "good" *B. connata* and putative *Bidens ×multiceps* in or near plots in the extreme backmarsh.

Given the global conservation rank of *Bidens eatonii*, the question of its occurrence at Ragged Rock Creek vs. the occurrence of *B. ×multiceps* is worth investigating, using modern molecular genetic techniques.

***Crassula aquatica* (Pygmyweed)**

Crassula aquatica (L.) Schoenl. [CRASSULACEAE] is a minute annual succulent forb that grows on brackish and fresh intertidal flats and shores, favoring relatively open substrate. It legally listed as "Endangered" in Connecticut, with a state conservation rank of S1 (CT-DEP 2004+) and global conservation rank of G5 (NatureServe 2009). It is unusual among most of the other plants that occur in these habitats in having an early phenology. It begins to bloom in May, and may essentially disappear by August, and thus may be thought of as a spring ephemeral of intertidal habitats. This phenology and its size have together likely contributed to its being overlooked until recently (botanical investigations in these habitats typically occur later in the growing season, when the majority of the species reach maturity). It was known in Connecticut only from tidal rivers in New Haven County, where it had not been documented since 1899. The first recent record was 1991 from a fresh (or in part oligohaline) tidal cove off the Connecticut River: while conducting seed bank experiments as part of his doctoral research, co-author N. E. Barrett discovered *Crassula* sprouting in the greenhouse from collected and potted intertidal sediments. Barrett later discovered a large population in the cove, and several other large populations have since been discovered in the lower fresh and brackish tidal section of the Connecticut River. The plant was first discovered at Ragged Rock Creek the year before our sampling, by K. J. Metzler, who found plants growing on wrack along the northern river levee.

During our work, we observed and recorded *Crassula* in plots only on or just behind the river levee, and occasionally on the levee front, and only along in the northern-most 650 m (approx.) of the marsh/river shore. The majority of plots in which it occurs have been classified as the *PHRAGMITES AUSTRALIS* (invasive) Community, *PHRAGMITES AUSTRALIS* (INVASIVE) / (MIX) Subtype. However, in all cases, the *Phragmites* on these sites is relatively low and diffuse compared with the mode for this type and subtype. One of these plots in this type and subtype is classified at a lower level as a *Schoenoplectus pungens* subtype: *S. pungens* is actually the dominant cover at this site. *Crassula* also occurred in the *PANICUM VIRGATUM* Community and the *SPARTINA PATENS* Community, *SPARTINA PATENS / ELEOCHARIS UNIGLUMUS* Subtype. At several sites with *Crassula*, the herb layer is very sparse and much unvegetated substrate is exposed. These are places where wrack deposits were in place long enough to kill the marsh vegetation, and then were recently moved away by high water events, at which point what may called primary succession begins on the bare sediments. Relatively high areal cover values for exposed substrate surface and low areal cover of litter or wrack were recorded in all plots with *Crassula*.

The surface substrate was in some cases mineral sand and gravel, but in most cases appears peaty but with a significant admixture of mineral. We observed no plants growing on wrack, as Metzler had the previous year.

The restriction of *Crassula* to only the northern section of the levee suggests an ecological gradient or gradients along the Ragged Rock Creek levee. This could be a salinity gradient, with Crassula reaching the upper limits of its salt tolerance at Ragged Rock Creek. Another possibility is a higher level of wave disturbance in this section of the level, which would contribute to less dense competing vegetation and a higher mineral content to the substrate.

Though restricted to a relatively small area of the marsh, *Crassula* individuals probably numbered in the millions, at least.

***Spergularia canadensis* (Canada sand-spurrey)**

Spergularia canadensis (Pers.) G. Don [CARYOPHYLLACEAE] is a small annual forb of brackish and saline intertidal marsh and shore habitats that. It is, together with *Crassula aquatica*, are the State-rarest of the State-listed plants known at Ragged Rock Creek. We observed and recorded *S. canadensis* in plots only on the river levee, just landward of the levee front, where there is much wave overwash. All plots in which *S. canadensis* occurred where classified as the *S.P* community. It occurred in 2 subtypes of this community recognized at the 25 cluster level: the *SPARTINA PATENS* /(FORB MIX) subtype and the *SPARTINA PATENS / ELEOCHARIS UNIGLUMUS* subtype. One plot was classified at the lowest hierarchical level (50 clusters?) as a *SPARTINA PATENS / SPARTINA ALTERNIFOLIA* subtype. *S. canadensis* frequent only along the southernmost several hundred meters of the river levee, and rarely observed north of that, in spite of the occurrence of very similar habitat and communities. This distribution suggests a south-to-north environmental gradient along the river front of Ragged Rock Creek marsh, which favors *S. canadensis* toward the south.

***Scirpus paludosus* ssp. *atlanticus* (Bayonet grass)**

Scirpus paludosus ssp. *atlanticus* [CYPERACEAE], for which we substitute the name *Bolboschoenus maritimus* ssp. *paludosus* elsewhere in this report and in our data, is a halophytic, rhizomatous perennial bulrush of relatively short stature with a northern and western distribution in North America, in Connecticut near the southern limit of its range in the east. *Scirpus paludosus* ssp. *atlanticus* is the name under which the taxon is currently legally listed as "Special Concern" in Connecticut; it has a state conservation rank of S2S3 (CT-DEP 2004+)and a global conservation rank (under a different name) of G5 (NatureServe 2009). The genus *Scirpus* has recently been revised taxonomically and broken up into several genera, but taxonomic authorities currently differ on the "correct" name for this species. This taxon is listed as *Schoenoplectus maritimus* (L.) Lye by the NRCS PLANTS database and Natureserve, while in the Flora of North America, it is listed as *Bolboschoenus maritimus* (L.) Palla ssp. *paludosus* (A. Nels.) T. Koyama (Smith *in* FNA 2002), as also in Flora Novae Angliae (Haines 2009). CT-DEP currently proposes change the name of this taxon on the Connecticut legal list to *Bolboschoenus maritimus* ssp. *paludosus*, and we have also chosen to use that name in this report.

Among all the plants of conservation concern at Ragged Rock Creek, *Bolboshoenus maritimus* ssp. *paludosus* probably is the most widespread occupies the greatest cumulative area, and for which there is the largest cumulative area of potential and occupied habitat. It was captured in the greatest number of random plots (18) of any of the 10 species of conservation concern. We observed and recorded *B. maritimus* ssp. *paludosus* most frequently in *Spartina patens*-dominated meadows in the interior of the study area. Fifteen of the 18 plots in where it was recorded were in the *SPARTINA PATENS* Community, and within this community most often in the *SPARTINA PATENS* / (MIX) Subtype (10 plots). We observed it rarely on the river levee, also in the *SPARTINA PATENS* Community, with a possibly stronger affinity for the levee noted toward the south end of the levee. In the *Spartina patens* meadows, it was frequently associated with lower microsites, away from ditches creek edges, where we could infer that evaporation likely raises salinity. Occasionally (one plot), we found it in the *SCHOENOPLECTUS AMERICANUS* Community, *SCHOENOPLECTUS AMERICANUS* / (MIX) Subtype. This site was one of the few places at Ragged Rock Creek where *Distichlis spicata* was abundant, which suggests locally higher salinities. It was rarely recorded in the *TYPHA ANGUSTIFOLIA* Community (1 plot), and the *PHRAGMITES AUSTRALIS* (invasive) Community (2 plots); at the sites with in the latter community.

Ragged Rock Creek is doubtless a stronghold of this species in Connecticut. We would estimate the number of genets is at least several thousand, and that the area of the marsh over which it occurs is at least 65 ha (based the distribution of random plots in which it was captured).

Bolboschoenus maritimus ssp. *paludosus* is reported to hybridize with *Bolboschoenus robustus*, which is ubiquitous and abundant in our study area, much more so than *B. maritmus* ssp. *paludosus*. This hybrid is reported to be common along the northern Atlantic coast in zones of sympatry (Smith *in* FNA Vol 23, 2002). Given this, we expected that it should occur in our study area, but observed no likely hybrid individuals. However, one of our collected specimens (Moorhead #6092 [DINH]), which Moorhead initially determined to be *B. robustus*, was determined by Arthur Haines to be the hybrid *B. maritimus* × *robustus* (Haines pers. comm.). Thus, we conclude that the hybrid is present in the study area, it evidently resembles *B. robustus* more than the other parent species, and we can make no estimate of its abundance in the study area. Given the much greater abundance of *Bolboschoenus robustus* in the study area than *B. maritimus* ssp. *paludosus*, there appears to be the potential for the latter species to be genetically "swamped" by hybridization.

***Scirpus cylindricus* (Salt marsh bulrush)**

Scirpus cylindricus [CYPERACEAE], for which we substitute the name *Bolboschoenus novae-angliae* elsewhere in this report and in our data, is a robust, rhizomatous perennial bulrush of brackish wetlands and shores that is geographically restricted to the eastern U.S. coast and Ontario (NatureServe 2009). It is currently legally listed as "Special Concern" in Connecticut; it has a state conservation rank of S3 (CT-DEP-NDDB 2009), and a global conservation rank (under a different name) of G5 (NatureServe 2009). As for the preceding taxon, authorities disagree on the most valid name for this taxon: the USDA PLANTS database and Natureserve list this taxon as *Schoenoplectus novae-angliae* (Britton) M.T. Strong, while Flora of North

America and Haines recognize *Bolboschoenus novae-angliae* (Britt.) S.G. Smith (Smith *in* FNA 2002; Haines 2009). CT-DEP currently proposes change the name of this taxon on the Connecticut legal list to *Bolboschoenus novae-angliae*, and we have also chosen to use that name in this report and data.

Bolboschoenus novae-angliae occupies a relatively small cumulative area in the Ragged Rock Creek study area. It has a bimodal ecological distribution. The habitat in which it was most often observed is creek bank and levee, where it occurred most of the time in small groups and occasionally longer small linear patches on the face and summits of creek banks. It occurred in a zone the lower boundary of which was about the upper limit of the *SPARTINA ALTERNIFLORA* Community, the upper boundary was the brow of the creek bank, or up to just a few meters landward of the brow. The second, evidently rarer, ecological setting in which it occurs are low places in the interior marsh at the heads of marsh creeks, where it occurs in patches larger in breadth than the creek bordering patches. Geographically, *Bolboschoenus novae-angliae* appears to be essentially absent from a zone of the marsh ~150 to ~300 meters wide bordering the river shore. It occurs along creeks well up into the backmarsh.

Bolboschoenus novae-angliae was recorded in 4 random plots, each classified as a different type. In the backmarsh, *B. novae-angliae* occurred near the head of a small creek that fed by a small fresh water stream, in the *PHRAGMITES AUSTRALIS* (invasive) Community. *B. novae-angliae* was recorded at the back of a large creek levee in the *JUNCUS GERARDII* Community, and on the summit of a small creek bank in the *TYPHA ANGUSTIFOLIA* Community. It was recorded in the interior of the ditched south central marsh, near the head of one of the original marsh creeks, in the *SCHOENOPLECTUS AMERICANUS* Community near a border with the *PHRAGMITES AUSTRALIS* (invasive) Community. *B. novae-angliae* was a minor associate in all the random plots, but it does occur at Ragged Rock Creek as the dominant species in patches up to several meters in breadth, three of which were sampled with subjective plots. This was too small a sample for the SPSS analysis to recognize at the higher levels in the classification, but this is a clearly a distinct, though rare, type at Ragged Rock Creek.

***Lilaeopsis chinensis* (Lilaeopsis)**

Lilaeopsis chinensis (L.) Kuntze [APIACEAE], the smallest member of the Carrot Family, is a tiny rhizomatous perennial that grows in loose to dense low mats on brackish intertidal flats and shores, frequently under a canopy of taller vegetation, on both peaty and mineral substrates, from the gulf coast north along the coast to Nova Scotia. It is tracked as a rare species from New York north. It legally listed as "Special Concern" in Connecticut, with a state conservation rank of S3 (CT-DEP 2004+) and global conservation rank of G5 (NatureServe 2009). It is restricted in the study area to a narrow zone on and adjacent to the river levee front, from the north end of the river shore south to the mouth of Ragged Rock Creek. It becomes most abundant at the far north end of the river shoreline. This distribution like that of several other species growing along the river shore, suggests a possible north-south environmental gradient along the river shore that affects the species distribution. *Lilaeopsis* occurs on the levee front in the *SPARTINA ALTERNIFLORA* Community, and defines the *SPARTINA ALTERNIFLORA / LILAEOPSIS CHINENSIS* Subtype. It also occasionally occurs in the *PHRAGMITES AUSTRALIS* (invasive)

Community, where it extends out to the levee front. *Lilaeposis* typically occurs as a linear colony, 1 meter or less wide in the dimension normal to the shoreline.

***Limosella subulata* (Mudwort)**

Limosella subulata [SCROPHULARIACEAE] is a tiny annual growing mainly on brackish to fresh intertidal flats and shores, occasionally on non-tidal shores, that is distributed along the northeast coast from VA to Labrador, and apparently disjunct in CA. It legally listed as "Special Concern" in Connecticut, with a state conservation rank of S3 (CT-DEP 2004+) and global conservation rank of G5 (Natureserve 2009). *Limosella australis* R. Br. is now widely accepted as the valid name for this taxon (Haines 2009, NatureServe 2009, NRCS 2009a).

The geographic distribution of *Limosella* in the Ragged Rock Creek study area was essentially same as that of *Crassula aquatica*: it is evidently restricted to the northmost 650 meters of the river/marsh shoreline. It co-occurs with *Crassula* in several communities, but it appears to be less common and abundant than *Crassula*: we captured it in only 1 random plot, versus 6 random plots for *Crassula*. Like *Crassula*, it is restricted ecologically to the river levee, and like it favors especially sites where vegetation is in early stages of redevelopment after a period of being mulched out by thick wrack deposits, followed by removal of the wrack by high water events, leaving behind an open to diffusely vegetated peat- or mineral-substrate. Of the five plots (4 subjective and 1 random) in which we recorded *Limosella*, only the one subjective plot we placed on the levee front does not coincide with an evident wrack deposit visible in summer 2005 aerial CIR orthophoto imagery. *Limosella* but extends lower into the tidal prism than *Crassula*, occurring also levee front, where we recorded it in the *SPARTINA ALTERNIFLORA* Community, *SPARTINA ALTERNIFLORA* Subtype, growing with relatively low, diffuse *Spartina alterniflora*. It likely occurs with *Lilaeopsis* in the *SPARTINA ALTERNIFLORA / LILAEOPSIS CHINENSIS* Subtype, as we have observed at other brackish shore sites. On the levee, we recorded in expressions of the *PHRAGMITES AUSTRALIS* (invasive) Community, *PHRAGMITES AUSTRALIS* (INVASIVE) / (MIX) Subtype, in which the *Phragmites* was relatively diffuse and low. At one of these sites, *Schoenoplectus pungens* is actually the dominant species, and the classification recognizes this as a *Schoenoplectus pungens* subtype at a lower level (32 clusters) in the classification. One of the sparsely vegetated levee sites with *Limosella* was classified as the *SPARTINA PATENS* Community, *SPARTINA PATENS / ELEOCHARIS UNIGLUMUS* Subtype.

***Ranunculus sceleratus* (Cursed crowfoot)**

Ranunculus sceleratus L. [RANUNCULACEAE] is an annual or short-lived perennial forb in the Buttercup Family that occurs in a variety of wetland habitats, including brackish and fresh tidal habitats, throughout North America and much of Eurasia (Fernald 1950; Natureserve 2009; Den virtuella Floran 2001). Its nativity to eastern North America has been questioned (Whittemore & Parfitt *in* FNA Vol. 3, 1997). It legally listed as "Special Concern" in Connecticut, with a state conservation rank of S3S4 (CT-DEP-NDDB 2009) and global conservation rank of G5 (Natureserve 2009). It is proposed for delisting in Connecticut in 2009, presumably because it has been demonstrated to be more common than originally thought. Ironically, in the context of our Ragged Rock Creek study area, it is the rarest of the plants of

conservation concern: a few plants were observed and recorded in a plot midway up the northern section of the river levee, at one of the sites sparsely vegetated due to recent completion of the wrack "move in, mulch out, move on" process, where it occurs with *Limosella* and *Crassula*.

***Atriplex glabriuscula* (Orache)**

Atriplex glabriuscula Edmondston [AMARANTHACEAE] is a northern-affinity annual forb in the Pigweed Family that occurs in saline and brackish marshes, shores, and strands along the coast in the Canadian Maritimes, Hudson Bay, northeast U.S. coast, and northern Europe. It is legally listed as "Special Concern" in Connecticut, with a state conservation rank of SU (CT-DEP 2004+) and global conservation rank of G4 (NatureServe 2009). This species often occurs in the same habitats as a common look-a-like, *Atriplex prostrata*. The two species can be distinguished with confidence only when bearing mature fruit, in the fall, and even then, individuals are often encountered that cannot be definitiely assigned to either species. Thus, in our sampling, we dealt with much the much the same problem as with *Bidens eatonii* and *Bidens connata*: during the period of our floristic sampling, plants were recognizable as *Atriplex*, but too immature to identify to species level. Because one of the possibilities was a species of conservation concern, we revisited a subset of the 99 plots in which *Atriplex* was recorded (revisiting all 99 plots was not practical), favoring plots on or near the river levee. Based on previous experience with *A. glabriuscula* on the lower Connecticut River, this would be the most likely part of the marsh for this species to occur. This investigation was hampered by a fall flood and very high spring tides had moved wrack around and generally beaten up the vegetation on and near the river levee, where most of the *Atriplex* were earlier recorded, so in many cases the original *Atriplex* plants recorded in the plots could not be relocated. At most plots that were revisited, plants that could be confidently assigned to *Atriplex prostrata* were observed and collected. No plants were observed or collected that could be assigned with high confidence to *Atriplex glabriuscula*, but at 2 revisited plots, plants that may arguably be assigned to *Atriplex glabriuscula* were observed and collected (Moorhead 5979 & 6000). Both plots are located just behind the southern river levee, one in the WRACK [~MIX] Community, and one in the *JUNCUS GERARDII* Community, *JUNCUS GERARDII / PHRAGMITES AUSTRALIS* (invasive) Subtype (transitional). The taxonomic uncertainty here is due to our finding many plants with "mixed" characters (i.e. plants with some characters of *A. prostrata* and some characters of *A. glabriuscula*), which suggests either hybridization or intraspecific variation within one or both taxa not published in the taxonomic literature.

Atriplex spp. were recorded in plots throughout the study area, typically in low abundance, in all communities except the *TYPHA ×GLAUCA* Community and the *SPARTINA ALTERNIFLORA* Community. More intensive study/inventory is needed before the occurrence of and distribution of *Atriplex glabriuscula* at Ragged Rock Creek can be confirmed.

Phragmites australis ssp. *americanus* (native common reed)

Among the more significant and exciting findings of this study was that *Phragmites australis* (Cav.) Trin. *ex* Steud. ssp. *americanus* Saltonstall, P.M. Peterson, & Soreng [POACEAE], the native, non-invasive subspecies of common reed, was extant at Ragged Rock

Creek. Though the existence in North America of both introduced and native varieties or subspecies of *Phragmites australis* has been in the taxonomic literature for some time (e.g., Fernald 1950), only recently has this been this been confirmed by modern molecular genetic techniques (Saltonstall 2004) and a set of diagnostic morphological characters been developed to reliably distinguish the two subspecies. When Saltonstall first published her work, *P. australis* ssp. *americanus* was known only historically from Connecticut. By 2006, the year of our study, two extant occurrences were suspected to exist but not yet confirmed, both in fresh tidal wetlands on the Connecticut River; these populations have since been confirmed (Capotosto pers. comm; Rosza pers. comm.). We discovered in our study area five discrete colonies of what we believed was native *Phragmites* (we had no previous experience with the taxon), submitted specimens to an authority, and our determination was confirmed. This is to date the only known extant occurrence of native *Phragmites* in a brackish tidal wetland in Conneciticut, and one of only four total occurrences known in the state (CT-DEP 2004+). It is not currently proposed for state-listing as Endangered, Threatened, or Special Concern, but with only 4 known occurrences, it meets the criteria for listing as either Endangered or Special Concern.

Native *Phragmites* stands occur on creek bank and creek levee in the *TYPHA ANGUSTIFOLIA* Community, *TYPHA ANGUSTIFOLIA* / (MIX) subtype. It occurs just behind creek levees and immediately adjacent to upland islands in *PANICUM VIRGATUM* Community. Two of the native *Phragmites* colonies occur immediately adjacent to much denser stands of introduced *Phragmites australis* ssp. *australis*.

P. australis ssp. *americanus* has been assigned a global conservation rank of G5T4, indicating it is considered "secure" globally, while acknowledging that it is threatened over the long term by competition and possibly introgression with invasive *P. australis* ssp. *australis* (Natureserve 2009). However, no state or provincial heritage program in the eastern part of its range has ranked it more common than an S3 (i.e., "vulnerable", fewer than 80 occurrences), and there is widespread interest among resource managers in its conservation.

A vegetation map of Ragged Rock Creek brackish tidal marsh

Ten major vegetation types were mapped at the Ragged Rock Creek brackish tidal marsh (Back matter-last page). The patch characteristics, total area, and proportion of the mapped vegetation types are presented in Table 6.

Table 6. Vegetation Pattern: patch number, size (square meters), total area (hectares) and percentage of vegetation community types (CT) units mapped in Ragged Rock Creek brackish tidal marsh

No.	*Mapped Community Type (CT)*	*No. of Patches*	*Patch size (m^2)*	*Total Area (hectares)*	*Percent (%)*
1.	*SPARTINA PATENS* / MIX CT *	767	365	28.02	22
2.	*PANICUM VIRGATUM* CT	1574	90	14.11	11
3.	*JUNCUS GERARDII* CT *	*	*	*	*
4.	*SCHOENOPLECTUS AMERICANUS* CT	1295	151	19.61	15
5.	*BOLBOSCHOENUS ROBUSTUS* CT	1601	89	14.21	11
6.	*TYPHA ANGUSTIFOLIA* CT	1113	156	17.38	14
7.	*TYPHA ×GLAUCA* CT	1160	59	6.80	5
8.	*PHRAGMITES AUSTRALIS* (invasive) CT	1378	197	27.18	21
9.	*SPARTINA ALTERNIFLORA* CT	**	**	**	**
10.	WRACK [~MIX] CT	**	**	**	**

* map unit *S.P CT* incorporates much of *J.G.* CT

** unmapped community types

The mosaic of the mapped vegetation types were not uniform (Table 3; Map Figure). Several observations are worth noting. The *S.P.* CT had the few, large patches and showed the greatest cover. The *P.A.* CT exhibited the same overall cover with twice as many patches of variable size. Conversely, the *B.R.* CT and *P.V.* CT had half as much cover occupied in many, small patches. The *T.XG.* CT have the smallest mappable area in scattered in a moderate number of small patches. *T.A.* CT and *SCH.A.* CT were intermediate in their expression of cover, size and number of patches. Several community types were not mapped by the computer. *S.A.* CT was too small: WRACK,CT was infrequent and lacked adequate control, and *J.G.* CT was incorporated into *S.P.* CT.

Map accuracy

The accuracy of the [first approximate] map classification is presented in Table 7 using a conservative contingency table approach. The overall accuracy was 45% based on the number of correctly classified samples along the principal diagonal. The Kappa coefficient was 0.33, a more conservative measure discounting chance agreement. Conversely, the numbers of off-diagonal entries demonstrates that substantial map confusion exists. The off diagonal pairwise intersections showed a number of misclassifications. The user's accuracy (misclassification or commission errors) was reasonable for the *S.A./MIX* (90) and the *P.A.* (74) types. However, the

user's accuracy was poor for the *P.V.* (6), *SCH.A.* (16)and *B.R.* (4) types. The user's accuracy is a measure of the classification's reliability or how accurately the label represents what actually exists. The producer's accuracy (omission errors) shows the misclassifications in terms of what types the mapmaker missed. Vegetation types least accurate (most omitted) were *T.XG.* (32) and *B.R.* (33). And vegetation types that were less moderately omitted were the *S.A* (48) and *P.A.*(50) types. Other community types were between these endpoints.

Table 7. Accuracy assessment of Ragged Rock Creek brackish tidal marsh 7 unit vegetation map. Key to the abbreviations for the vegetation types are presented in the description of the units. Overall accuracy of first approximation = 45%; *Kappa* = 0.33. Correctly classified cases fall on the principal diagonal.

Observed data (Field Plots)

Predicted data (Mapped polygons) Classes	*S.P./MIX*	*P.V*	*SCH A*	*B.R.*	*T.A.*	*T.XG.*	*P.A.*	*Map total*	*User's accuracy (%)*	*Commission Error*
S.P./MIX	142	1	3	0	5	0	7	158	90	10
P.V.	32	5	6	4	14	3	24	88	6	94
SCH A	60	0	19	1	18	1	19	118	16	84
B.R.	12	1	3	3	23	8	32	82	4	96
T.A.	23	1	6	0	43	24	13	110	39	61
T.XG.	6	0	3	0	6	19	9	43	44	56
P.A.	23	1	6	1	2	4	104	141	74	26
Field total	298	9	46	9	111	59	208	740		
Producer's accuracy (%)	48	56	41	33	39	32	50			
Omission Error	52	44	59	67	61	68	50			

CONCLUSIONS

This study presented a carefully conducted baseline vegetation characterization and mapping study, involving detailed species-level vegetation descriptions. The results of the hierarchical cluster analysis and fidelity tests distinguished a set of nested community types that compared very favorably with existing vegetation descriptions known from previous studies of brackish community types in Connecticut. Most importantly, the geographical context was provided for species of conservation interest, *i.e.*, state listed plants and invasive plants, especially *Phragmites*. The vegetation map provided the critical baseline for invasive *Phragmites* eradication and subsequent restoration monitoring. The mixed results of the map accuracy assessment suggests that improvements to the protocol are needed. Our dense array of

926 precisely georeferenced plots, photographs, quantitative vegetation data, and voucher specimens, provide a robust baseline which will enable an evaluation of the marsh response in the future to management, climate change, sea-level rise, or other phenomena. This study demonstrated the utility of this approach for mapping large and heterogeneous wetland complexes and taking baselines for management and monitoring actions.

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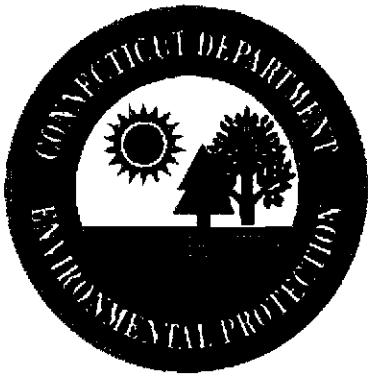

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MAJOR VEGETATION TYPES OF RAGGED ROCK CREEK [BRACKISH TIDAL MARSH] (a first approximation)

(KEY TO LEGEND: S.P. = SPARTINA PATENS, P.A. = PHRAGMITES AUSTRALIS, T.A. = TYPAHA ANGUSTIFOLIA, SCH.A. = SCHOENOPLECTUS AMERICANUS, B.R. = BOLBOSCHOENUS ROBUSTUS, P.V. = PANICUM VIRGATUM)