Factors Affecting Survival of Planted Materials in Marley Creek Constructed Freshwater Tidal Marsh, Maryland

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The Maryland State Highway Administration constructed a 0.8-hectare freshwater tidal marsh on Marley Creek, Anne Arundel County, as mitigation for wetlands filled during the Route 10 extension. Research was initiated in June 1987 at the completion of site construction to investigate aspects of the initial stages of marsh development. Vegetation was sampled in the constructed marsh and in a neighboring natural marsh by using a random sampling design to determine planted species survival, species occurrence, and vertical distribution. June and October 1987 data indicate that the survival rate of the planted species (*Scirpus americanus*, *Peltandra virginica*, and *Leersia oryzoides*) is not solely dependent on placement within the tidal range. Although *Peltandra virginica* and *Leersia oryzoides* were planted within the elevation ranges determined for these species in the natural marsh, they suffered over 50 percent and 90 percent mortality, respectively. The data suggest that other factors such as life history, pH, and soil properties are important in determining survival of planted materials. By October 1987, the site was rapidly colonized with 28 additional plant species, most of which were found within the observed naturally occurring tidal range.

State highway authorities are increasingly challenged to construct wetlands successfully to satisfy permit conditions issued pursuant to state and federal wetland protection laws. The permit usually stipulates conditions under which wetlands must be constructed to insure compensation for wetland loss. Often the conditions require an 85 percent survival of planted materials per unit area, as determined at the beginning of the second growing season (*1*). If this survival rate is not met, the applicant may be required to reconstruct the wetland. Thus, improper design or construction could result in considerable costs to the applicant.

Wetlands are not necessarily easily constructed, and the 85 percent survival rate is neither readily achievable nor scientifically based. Although guidelines for planting these sites are available (*1–5*), the science or technology of wetland construction is still new and experimental. Most of the literature concentrates on the techniques to establish tidal salt and brackish marshes. Although the practice of constructing marshes has become relatively commonplace, follow-up studies evaluating the factors influencing the success of these communities are sparse. There is a growing demand to identify the factors affecting the survival rates of planted materials and the colonization by invading species in constructed freshwater marshes.

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In June 1987, the Maryland State Highway Administration completed construction of a 0.8-hectare freshwater tidal marsh on Marley Creek, Anne Arundel County, as a mitigation project for impacts associated with the construction of the Arundel Expressway. Research was initiated at completion of site construction to investigate aspects of the initial stages (0–2 years) of marsh development. Reported in this paper are the results for the first growing season extending into the following spring (May 1987 through June 1988).

The objective of this study was to observe the vegetation dynamics of a constructed freshwater tidal marsh, specifically the revegetation process and the survival of planted materials. Elevation was used to evaluate the extent to which tidal inundation determines individual species distribution. To accomplish this, the relative elevation ranges of individual species were determined and compared for the constructed marsh and for a neighboring natural marsh located across the Marley Creek channel from the constructed marsh. Since the planted species were placed within elevation ranges found for these and other wetland species in the natural marsh, this study permitted the identification of additional factors influencing survivorship.

AREA DESCRIPTION

The study site encompasses the constructed and natural freshwater tidal marshes adjacent to Marley Creek (39°9′10″ N, 76°35′15″ W), Harundale, Anne Arundel County, Maryland. Marley Creek is an estuary in the Chesapeake Bay watershed that joins the Patapsco River just south of Baltimore. The study area is located approximately 8 km upstream from the Patapsco River and less than 1 km from the end tidal influence. The average width of the creek measured at the study site is 15 m. At the Route 10 bridge, Marley Creek drains an area of 20.99 km^2.

Tides are diurnal, with a mean tide level at 0.18 m; predicted mean and spring tides are 0.34 m and 0.4 m, respectively (*6*). Mean low water (MLW) is −0.01 m below the National Geodetic Vertical Datum (NGVD); mean high water (MHW) is 0.33 m above NGVD.

The natural marsh sediments are classified as mixed alluvial land that consists of soil materials ranging from sand to clay (*7*). Land excavated to construct the new marsh was classified as Matawan loamy fine sand, 2 to 5 percent and/or Muirkirk

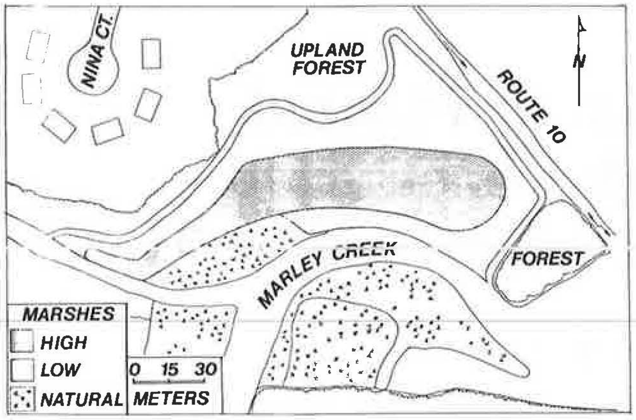

FIGURE 1 Marley Creek freshwater tidal constructed and natural marshes, Harundale, Anne Arundel County, Maryland.

loamy sand, 10 to 15 percent slopes. The upper horizons of these soils were removed to expose the underlying parent material of fine sandy mottled clay. Profiles at 1.02–1.52 m are described as very hard, firm, sticky and plastic, and strongly to very strongly acid (*7*). Measurements of soil pH taken September 1988 revealed a range of 3.6–6.2 for the constructed site sediments, in contrast to the constant 6.1 readings for the natural marsh sediments.

The Maryland State Highway Administration excavated what was originally forested upland to attain a freshwater tidal marsh (Figure 1). The original conceptual drawings were developed by Environmental Concern, Inc. (*8*). The constructed marsh was designed to have two zones, distinguished by elevation and by planted species. The plant species selected included those that (a) were naturally occurring in the area, (b) have been successfully used in wetland establishment projects, and (c) have been successfully developed and propagated in nurseries (*1*). The high marsh was to be graded to elevation 2.0 ± 0.20 ft above NGVD and planted with Olney three-square (*Scirpus americanus*) and rice cutgrass (*Leersia oryzoides*). Arrow arum (*Peltandra virginica*) was planted in the low marsh that had a design grade of 1.2 ± 0.2 ft NGVD. The study area (Figure 1) includes the 0.8-hectare constructed marsh and the neighboring natural freshwater tidal marsh system. Grading was completed in May 1987; plantings were made between May 11 and 15 and June 9 and 13, 1987.

METHODS

The study area (including constructed and natural marsh) was sampled using a 6.1-m grid system. To provide data amenable to statistical data analysis, sample sites were located by using pairs of random numbers as coordinates in measuring with a tape from reference stakes. At least one point was located within each of 300 grids and permanently marked with reinforcing steel (rebar), which served to define the center point of a 1-m^2 circular sample quadrat. All vascular plant species (including seedlings) were recorded in each quadrat during July and October 1987. Species names follow Gleason and Cronquist (*9*). The numbers of live and dead planting units of *Scirpus americanus*, *Peltandra virginica*, and *Leersia oryzoides* were recorded in each quadrat during the July 1987 sampling.

Survival of *Peltandra virginica* was measured by taking a monthly census of 1,000 initial cohorts in permanent plot during the first growing season (June through October 1987) and the following spring (May 1988). Since the planting unit of *Scirpus americanus* was comprised of three to five plants per plug, individual cohorts could not be distinguished in the field; therefore, a proper census of survival of individuals could not be assessed. The rapid spread of *Scirpus americanus* also precluded the identification of individual planting units and measurement of survival for these units after July 1987. Survival for *Scirpus americanus* was measured for individual planting units as determined in the July 1987 quadrat sampling and related to elevation data.

Elevations were determined within each quadrat to the nearest 1.5 cm by transit and stadia board referenced to a Maryland Department of Transportation benchmark. More than one reading was taken depending on the quadrat surface relief (topographic conditions). Elevation data on the constructed site consisted mostly of one reading since the grading was relatively uniform, whereas elevations were read for each individual species on the natural marsh because of the microrelief.

RESULTS AND DISCUSSION

By July 1987, approximately 1 to 2 months after planting, the percent survival of *Scirpus americanus*, *Peltandra virginica*, and *Leersia oryzoides* were 65, 68, and less than 10 percent, respectively. Although *Peltandra virginica* incurred additional losses throughout the first growing season, most individual plants that survived by October 1987 overwintered and sprouted in May 1988. With the exception of one patch, which is completely devoid of vegetation, losses in *Scirpus americanus* were spatially compensated for through its rapid growth and attainment of 100 percent cover in many plots. The 65 percent survival is an underestimation because much of the *Scirpus* that seemed to die during the hot midsummer months lay dormant and sprouted later in September and October when the conditions were less severe. *Leersia oryzoides* suffered the greatest mortality rate apparently because of a combination of factors, including soil properties, reflectance of the soil, competition, and vandalism.

Several factors were expected to affect the population dynamics of species planted at the Marley Creek marsh. Critical factors identified for coastal wetland and dune restorations include wind and/or water transport and erosion, severe storms, available soil water, soil water salinity, soil nutrients, tide, drought, sudden temperature flucuations, ice damage and scouring, accretion, human activities, root damage by animals, weak planting stock, improper handling and/or storage of planting stock, and poor transplanting procedures, such as shallow planting and inadequate firming of sand around transplant base (*1, 10–12*).

Figure 2 illustrates the survival curve of *Peltandra virginica*. A referral to the aforementioned list of factors would show that apparently none of these contributed significantly to the demise of this planting effort. The low marsh was graded to meet design criteria and planted with fertilizer to insure suf-

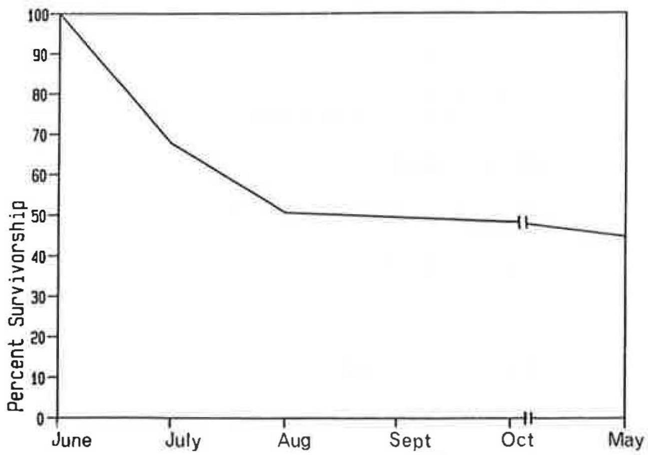

FIGURE 2 Percent survival of planted *Peltandra virginica* as a function of time (June 1987–May 1988).

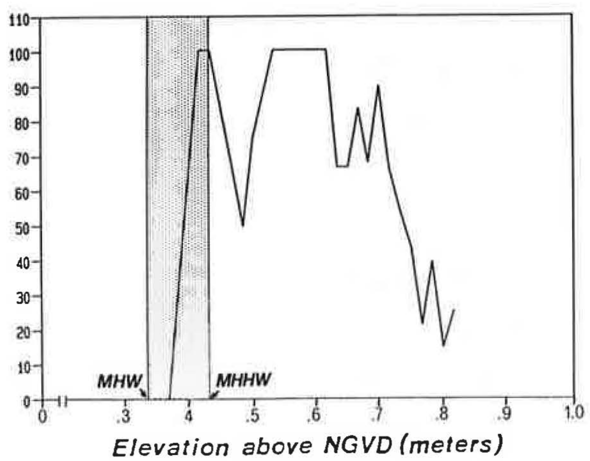

FIGURE 3 Percent survival of planted *Scirpus americanus* as a function of elevation above NGVD (July 1987).

ficient nutrient availability. Comparisons to the distribution of this species with respect to elevation in the natural marsh confirmed that the constructed low marsh elevations were within the range for the naturally occurring *Peltandra virginica* (see Figure 4b). Levels of mortality at various elevations within the low marsh revealed no significant preference of planted *Peltandra virginica* for any particular elevation. The mortality of *Peltandra virginica* cannot, therefore, be attributed to planting elevation. There were minimal losses due to vandalism (i.e., plants pulled out) and erosion of sediments from the high marsh edge into the low marsh. It appears that a major factor influencing survival may be the sediment properties such as particle size and pH, which are yet to be analyzed in detail. Initial measurements indicate a fine sandy mottled clay with a pH as low as 3.6.

Measurements of percent survival for *Scirpus americanus* (Figure 3) suggest that planting elevation may have affected its potential success in getting established in the constructed marsh. *Scirpus americanus* is not present in the natural marsh; therefore there was no basis for comparison within the study

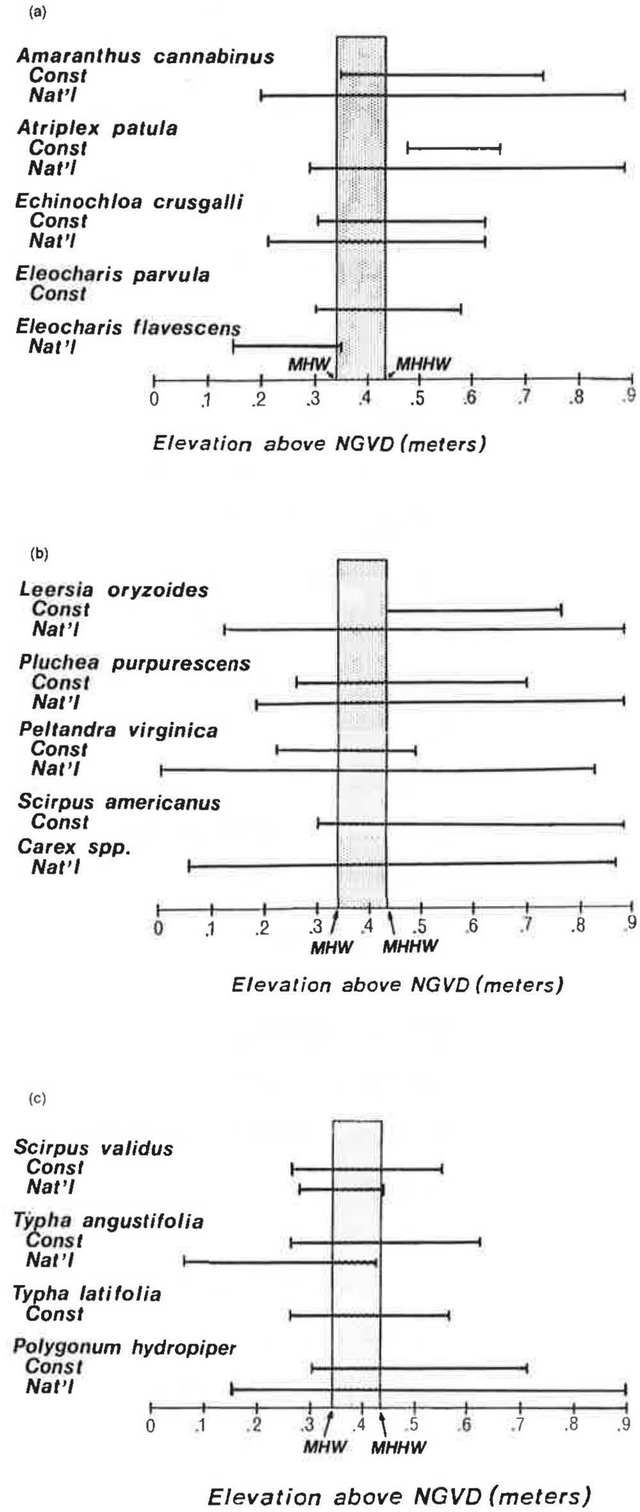

FIGURE 4 Elevation of plant species at Marley Creek constructed (Const) and natural (Nat'l) marshes. (a) *Amaranthus cannabinus, Atriplex patula, Echinochloa crusgalli, Eleocharis parvula, Eleocharis flavescens*; (b) *Leersia oryzoides, Pluchea purpuresceus, Peltandra virginica, Scirpus americanus, Carex* spp.; (c) *Scirpus validus, Typha angustifolia, Typha latifolia, Polygonum hydropiper*.

TABLE 1 PLANT SPECIES THAT COLONIZED MARLEY CREEK CONSTRUCTED MARSH BY OCTOBER 1987

Scientific Name	Common Name
Amaranthus cannabinus	Water Hemp
Aster subulatus	Annual Salt Marsh Aster
Atriplex patula	Marsh Orach
Carex spp.	Sedge
Cyperus Iria	Umbrella Sedge
Cyperus ovularis	Umbrella Sedge
Cyperus polystachyos	Umbrella Sedge
Cyperus retrorsus	Umbrella Sedge
Cyperus rivularis	Shining Cyperus
Cyperus strigosus	Straw-colored Cyperus
Cyperus tenuifolius	Umbrella Sedge
Echinochloa crusgalli	Barnyard grass
Eclipta alba	Eclipta
Eleocharis flavescens	Spike-rush
Eleocharis parvula	Dwarf spike-rush
Hibiscus moscheutos	Rose Mallow
Juncus acuminatus	Tapertip Rush
Juncus effusus	Soft rush
Osumunda regalis	Royal Fern
Panicum dichotomiflorum	Panic Grass
Pluchea purpurascans	Annual Salt marsh Fleabane
Polygonum hydropiper	Common Smartweed
Polygonum Persicaria	Smartweed
Pontedaria cordata	Pickeralweed
Sagittaria latifolia	Big-leaved Arrowhead
Scirpus validus	Soft-stemmed Bulrush
Typha angustifolia	Narrow-leaved Cattail
Typha latifolia	Broad-leaved Cattail

area to determine its normal elevation range under natural conditions. With the exception of a low value around 0.45 NGVD, the *Scirpus* generally maintained 100 percent survival between 0.40 and 0.60 NGVD and then followed a pattern of increased mortality with increased elevation. The low value at 0.45 NGVD appears to reflect the soil conditions in one patch of the marsh that remained devoid of vegetation throughout the first growing season.

Leersia oryzoides was planted within elevation ranges for which it was found in the natural marsh (Figure 4), yet it suffered the greatest mortality of all the species. The high mortality of *Leersia oryzoides* cannot be attributed to planting elevation and associated parameters (e.g., hydroperiod). Some losses were because of vandalism: vandals threw some of the plants out of the flats before planting, and it is assumed that the added shock may have resulted in the death of these few after planting. Initial observations suggest that reflectance of the sediment surface may have been a major contributor to the high mortality rates. The *Leersia* was primarily planted in a patch of light-colored, almost white sediments. In an adjacent area where the sediments were relatively darker, *Leersia* survived. When highly reflective aluminum tags were placed under a couple of these plants, they died within 2 to 3 days, suggesting that this species may be very sensitive to the high reflectance property of the light sediments.

The high mortality of *Leersia oryzoides* also may be attributed to sediment characteristics of the constructed marsh. Although *Leersia* is found at elevations well above mean high high water (MHHW) in the natural marsh, the substrate of fine silts remain saturated, providing sufficient water availability. In constrast, the sand-clay substrate of the constructed marsh at comparable elevations is not always saturated and appears to be more dependent on precipitation events than on the tidal influence. In terms of elevation, the potential distribution of *Leersia oryzoides* may be significantly more narrow on the constructed site because of the sediment properties.

In addition to the planted species, the elevation ranges of major invading species were also recorded and compared with distributions at the natural marsh (Figure 4a–c). With the exception of *Scirpus validus*, plant species invading the constructed marsh occupied a more narrow range. This narrow range may reflect the germination requirements of the individual species; that is, the seeds germinated where the moisture and temperature conditions were most suitable. If this is the case, then during the following growing season one might expect a shift in distribution as determined by differences in storm events, tide cycle, and temperature at seed set. The recorded distributions may also be more permanent and represent the realized niche breadth under various sediment conditions. In providing more saturated conditions, the silt substrate of the natural marsh may widen the potential elevation distribution range.

Included in Figure 4 is a comparison of *Scirpus americanus* and *Carex* species. The purpose of this comparison is to demonstrate that the natural marsh surface extends well above the MHHW level of the tides and yet it is still a wetland. Although the constructed wetland was graded, in part, higher than the design grade, the distribution of *Scirpus americanus* illustrates that these elevations are within the range found under natural conditions. Table 1 provides a list of all 28 plant species that colonized the constructed wetland within the first growing season.

CONCLUSIONS

Although elevation may be an important factor in the design and construction of a freshwater tidal marsh, other factors may have a significant role in determining the survival of planted materials. Comparison of a natural system with a constructed marsh revealed that differences in sediment properties, including grain size, reflectance, and pH may limit the potential distribution for both planted and invading species in the constructed marsh. Therefore, it is recommended that potential physical limitations of the sediment base be evaluated if, in the planning of marsh construction, the sediment base differs in composition from that of neighboring natural marshes. If an area is to be excavated to parent material, information should be gathered regarding the physical properties of these sediments.

ACKNOWLEDGMENTS

Financial support for this study was provided by the National Wildlife Federation and Environmental Concern, Inc. Appreciation is extended to several people who have contributed invaluable assistance and endured many very hot days in the marsh to ensure the success of this study. These include John Magistro, Lisa Kensler, Joe Albiston, Richard Wulff, and Scott McLendon.

Special thanks go to Ed Garbisch for his support and encouragement during all facets of this research.

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Publication of this paper sponsored by Committee on Landscape and Environmental Design.