Marsh Restoration Using Thin Layer Sediment Addition: Initial Soil Evaluation

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INTRODUCTION

Many coastal wetlands display degradation attributable to various factors including land development, erosion, salinization, and a lack of sediment inputs (Barras et al. 2003; Baumann et al. 1984). Additionally, conditions may worsen as impacts associated with sea level rise as well as increases in storm frequency and intensity exacerbate marsh stressors (Hauser et al. 2015). Marshes naturally exhibit a mosaic of vegetated and open water areas (Adamowicz and Roman 2005). However, studies document marsh fragmentation and subsequent degradation by examining an increase in the conversion of vegetated areas to open water (Figure 1; Turner 1997; Day et al. 2000).

FIGURE 1. Site conditions in a degrading marsh near Avalon, New Jersey, USA in which portions of the marsh have shifted from vegetated areas to shallow open features that display signs of erosion and subsidence (left). Within vegetated sections of the marsh, Spartina alterniflora roots form a dense root mat that helps to stabilize marsh soils (right).

Conceptual models of marsh degradation describe three processes: 1) drowning - whereby accretionary processes are outpaced by sea level rise, 2) edge retreat - caused primarily by wave erosion at lower marsh margins, and 3) marsh pond (sometimes referred to as pools or pannes) collapse - in which open water areas fail to maintain elevation relative to rising sea level and expand through continued edge erosion (Mariotti 2016). DeLaune and others (1994) described the process as pond initiation, in which newly formed open water areas allow for marsh degradation via erosion, collapse, and other mechanisms. In response, wetland restoration projects have been implemented over the past three decades to stabilize and enhance marsh ecosystems (Warren et al. 2002). Techniques include erosion control, invasive species removal, and re-establishment of natural wetland vegetation and tidal flow regimes (GMCHRS 2004; Jackson 2009). Notably, in a recent article Smith and Niles (2016) highlights the need for improved approaches to documenting marsh degradation and determining the potential benefits and/or risks associated with marsh restoration.

Broome and others (1988) identified important components in marsh restoration including elevation of the site in relation to tidal regime, slope, exposure to wave action, soil chemical and physical characteristics, nutrient supply, salinity and availability of viable propagules for revegetation. These factors highlight the need for restoration strategies that counterbalance subsidence, support a stable platform for plant growth, and keep pace with expected sea level rise while maintaining natural patterns of wetland hydrology and vegetation. The intentional application of sediments into marsh habitats has the potential to help achieve restoration goals by allowing the marsh to maintain elevation despite ongoing subsidence or sea level rise.

Dredged materials have been utilized for many years in wetland creation and restoration projects (Faulkner and Poach 1996; Craft 1999; Cahoon and Cowan 1988). Commonly, materials are deposited within diked containment areas, adjacent to shorelines, or in open water until target elevations are reached (Landin et al. 1989; USACE 1983; Berkowitz et al. 2015). The placement of dredged material

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directly onto the marsh surface remains challenging due to the need to achieve target elevations while maintaining or rapidly establishing the native plant communities that stabilize marsh soils (DeLaune et al. 1994). As a result, much interest has focused on the application of thin layers of dredged materials within existing marshes to support marsh elevation while enhancing existing habitat.

Wilbur (1992) defined thin layer placement techniques as the application of dredged materials to a thickness that does not transform the receiving habitat's ecological functions. Others have defined thin layer placement utilizing a layer thickness criteria ranging from as little as a few centimeters up to 50 cm. Sediment application typically occurs via the spraying of fluidized dredged materials onto the marsh surface (Figure 2). Ray (2007) provided a review of thin layer placement case studies. For example, Reimold and others (1978) performed initial small-scale studies in which *Spartina alterniflora* successfully recovered following the placement of 23 cm of dredged materials on the marsh surface. Placement of thick layers reduced or prevented plant recovery by rhizomes (Ford et al. 1999; Schrift et al. 2008). Other studies examined thin layer placement techniques designed to restore or enhance degraded marshes through evaluation of plant communities (Pezeshki et al. 1992; Ford et al. 1999), invertebrates (Croft et al. 2006), soil organic matter and bulk density (Slocum et al. 2005), and marsh resilience following a disturbance (Stagg and Mendelssohn 2011).

FIGURE 2. Site preparation prior to thin layer sediment application included placement of coir logs to target areas receiving sediment additions (top). Thin layer placement of dredged materials involves spraying a dredged sediment slurry onto the marsh surface (bottom). (Photo courtesy of Tim Welp)

TESTING THIN LAYER SEDIMENT TO RESTORE DEGRADING SALT MARSH IN NEW JERSEY

Current efforts are utilizing thin layer applications of dredged materials to address concerns regarding marsh degradation and enhancement of marsh resilience and habitat within a large wetland complex located near Avalon, New Jersey, USA (Figure 3). The *S. alterniflora*-dominated marsh displayed several signs of instability including erosion, expansion of open water areas, and fragmentation. Sediment placement occurred between November 2015 and March 2016. Dredged sediments were obtained during channel maintenance from the federally-maintained New Jersey Intracoastal Waterway following Superstorm Sandy. Sediment placement depths ranged from 5-20 cm in vegetated areas and up to 50 cm in open water portions of the marsh. Primary project goals include stabilization of the marsh platform, increasing the elevation of recently developed open water areas to promote vegetation establishment, and evaluating the potential benefits of thin layer sediment application for other restoration activities. Stabilization of the degraded Avalon marsh will also provide continued benefits to the barrier island community of Avalon by maintaining protection from waves and erosion. Monitoring efforts to document restoration outcomes began in 2016 and will continue during 2017 and beyond.

Project partners will be monitoring responses of vegetation, fauna, and other factors to the thin layer placement effort, while our team is focused on soil physical, nutrient and biogeochemical properties. Soils provide the physical substrate supporting plant growth and soil microbial communities have been shown to respond quickly to changes in the environment (Slocum et al. 2005; Harris 2009). As a result, we believe that examining soil physical, nutrient, and microbial properties associated with restoration techniques remains an important component in evaluating restoration trajectory and success (Table 1; Berkowitz 2013; Berkowitz and White 2013). Prior to dredged material placement, soil core samples were collected in vegetated and open water areas within the restoration footprint and in adjacent control regions of the marsh (Figure 4). The combination of pre-application data with subsequent soil collections will allow investigation of baseline soil property differences between vegetated and open water features in the marsh as well as change detection within control and treatment areas where thin layer applications have occurred.

Figure 3. Location of the tidal marsh in coastal New Jersey, USA. Note the location of the New Jersey Intracoastal Waterway, the source for dredged materials utilized in the thin layer application. The areas highlighted in white outline the portions of the marsh receiving thin layer sediment application.

FIGURE 4. Sampling conditions differed between open water areas and *S. alterniflora*-dominated sections of the marsh as indicated by the lack of soil stability in the open water areas. (Photo courtesy of Bobby McComas)

TABLE 1. Soil parameters being evaluated following thin layer sediment application and anticipated marsh response

Physical properties		***Anticipated marsh response***
Bulk density Root distribution	Particle size Moisture content	Soil horizon development; bulk density decrease; dredge material incorporated into the original soil material
Nutrient status		
Soil organic matter Total phosphorus Extractable nitrate Total dissolved nitrogen Dissolved organic carbon	Total carbon Total nitrogen Extractable ammonium Soluble reactive phosphorus	Accumulation of organic C, N, and P; C sequestration; improved nutrient cycling over time
Microbial activity		
Microbial biomass carbon Potentially mineralizable nitrogen	Microbial biomass nitrogen	Microbial communities become established; marsh functions dependent on microbes return to comparable marsh levels

We anticipate the partial recovery of marsh functions following dredged material placement based upon previous studies. For example, Craft and others (1999) examined constructed and planted *S. alterniflora* marshes over a 25-year period reporting accumulation of soil organic C and soil N and decreases in bulk density. However, soil properties did not correspond with values observed in a natural marsh. Thin layer placement applications may increase recovery timelines, due to the presence of potential seed sources for vegetation and microbial populations. Microbial communities represent a small but active nutrient pool in the soil environment, regulating biogeochemical cycling and bioavailability of nutrients (White and Reddy 2001). As marsh functions develop over time we expect soil horizon development, organic C, N, and P accumulation, as well as bulk densities and nutrient cycling to approach levels identified in the control marsh areas. Analysis of pre-treatment and initial post-treatment samples collected after thin layer placement of dredged materials are ongoing and should lend insight into the implications and potential benefits of restoration techniques utilizing thin layer sediment application (Figure 5).

For further information on this project, please feel free to contact the senior author or the project leads Monica Chasten from the USACE Philadelphia District and Dave Golden from the New Jersey Department of Environmental Protection Division of Fish and Wildlife. ■

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FIGURE 5. *S. alterniflora* emerging from dredged materials utilized for marsh restoration via thin layer sediment application. The photos were taken approximately six months (a, b), nine months (c), and 18 months (d) after placement of dredged material.

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