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Recovery of salt marsh vegetation after removal of storm-deposited anthropogenic debris: Lessons from volunteer clean-up efforts in Long Beach, NY

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ABSTRACT

Recovery of vegetation on a Long Island, NY salt marsh was investigated after the removal of hurricane-deposited large wooden debris through managed clean-ups involving volunteers. Two years after the removal of the debris, vegetation cover and species composition were not significantly different from controls. There was no significant difference in vegetation recovery among fall and spring debris removal treatments. Initial vegetation cover of the experimental and control plots was 95.8% and 1.2%, respectively; after two growing seasons cover was 78.7% and 71.2%, respectively. The effects of trampling by volunteers during debris removal were monitored and after one growing season, trails used during a single clean-up effort had a mean vegetation cover of 67% whereas those that were used during multiple clean-up efforts had only 30% cover. We use the results of this study to offer guidance for organizing effective salt marsh clean-up efforts.

1. Introduction

Salt marshes are vital coastal ecosystems located between land and salt water. Many critical ecosystem services are provided by salt marshes, in part because of their position between the terrestrial and marine habitats (Costanza et al., 1997; Levin et al., 2001; Barbier et al., 2011; Shepard et al., 2011). Salt marshes serve as critical habitats for numerous vertebrate and invertebrate species by providing shelter, feeding grounds, and nursery grounds (Boesch and Turner, 1984; Raposa et al., 2009; Barbier et al., 2011). In addition, they provide substantial indirect and direct benefits to humans including coastal protection, carbon/nutrient sequestration, water purification, and maintenance of commercial fish and shellfish species (Bromberg and Bertness, 2005; Costanza et al., 2008; Gedan et al., 2009; Barbier et al., 2011; Artigas et al., 2015). Globally, salt marsh vegetation has been estimated to sequester about 5–87 teragrams of carbon per year (Barbier et al., 2011; Artigas et al., 2015). In addition, they improve water quality by nutrient and/or pollutant uptake (Casagrande, 1997; Gedan et al., 2009; Barbier et al., 2011). Residential areas also substantially benefit from the role that these ecosystems have in erosion control and coastal protection, particularly during storm events (Casagrande, 1997; Costanza et al., 2008; Morgan et al., 2009; Barbier et al., 2011; Gedan et al., 2011; Shepard et al., 2011). Thus, negative stresses to salt marshes have the potential to cause large economic losses to humans via flooding, erosion, and reduced waste treatment and food production (Gedan et al., 2009; Brisson et al., 2014).

Salt marshes of the mid-Atlantic provide habitat for a wide range of vertebrate and invertebrate species that find shelter and protection from predators (Boesch and Turner, 1984). Migratory and residential birds use salt marshes as foraging and nesting grounds (Levin et al., 2001; Cardoni et al., 2007; Raposa et al., 2009; Conway et al., 2010) and some threatened or endangered species reside on salt marshes (Casagrande, 1997; Niedowski, 2000). Salt marshes are also of great economic, recreational, and educational importance to humans (Barbier et al., 2011). Major fisheries, including shrimp, oysters, clams, and fish are dependent on salt marshes (Boesch and Turner, 1984; MacKenzie and Dionne, 2008; Barbier et al., 2011) and these habitats encourage tourism and recreation activities (e.g., birdwatching) (Johnston et al., 2002; Crossett et al., 2004; Gedan et al., 2009; Moreno and Amelung, 2009; Barbier et al., 2011).

Along the east coast of the United States, salt marsh plant species composition is typically divided into low, mid, and high marsh zones (Niering and Warren, 1980). The low marsh is composed of vegetation that is flooded daily and highly salt tolerant, such as the tall form of native smooth cordgrass *Spartina alterniflora* Loisel. (Mooring et al., 1971; Stalter, 1973; Gallagher et al., 1988; Niedowski, 2000; Bertness et al., 2002). The mid marsh and the high marsh are distinguished based on flooding frequency, with the high marsh generally flooding less - only during higher tides (Hladik and Alber, 2014). The mid marsh consists of the medium form *Spartina alterniflora* and the high marsh is dominated by the short form of *Spartina alterniflora*, saltgrass *Distichlis spicata* (L.) Greene, and slender glasswort *Salicornia maritima* Wolff & Jefferies

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(Adams, 1963; Amen et al., 1970; Mooring et al., 1971; Gallagher et al., 1988; Niedowski, 2000; Hladik et al., 2013). Other common plant species in the high marsh are the salt marsh aster *Symphyotrichum tenuifolium* (L.) G.L. Nesom and lavender thrift *Limonium carolinianum* (Walter) Britton (Redfield, 1972). Salt pans may also be present as shallow depressions that are devoid of vegetation and distributed throughout the mid and high marsh (Sripanomyom et al., 2011; Escapa et al., 2015). The Jesuit's bark *Iva frutescens* L. and common reed (native and non-native) *Phragmites australis* (Cav.) Trin. ex Steud. are two plant species at the high marsh edges (Niering and Warren, 1980; Bart and Hartman, 2003; Silliman and Bertness, 2004; Saltonstall et al., 2014).

A range of natural and human influenced disturbances can impact salt marsh vegetation, leading to die-off and possible regrowth. Wild fires (Baldwin and Mendelssohn, 1998; Conway et al., 2010; Lonard et al., 2012), herbivores (Ellison, 1987; Gedan et al., 2009; Bertness et al., 2014; Coverdale et al., 2014), and accumulation of dead plant material known as wrack (Hartman et al., 1983; Valiela and Rietsma, 1995; Baldwin and Mendelssohn, 1998; Lottig and Fox, 2007) have the potential to damage healthy salt marshes. Additionally, hurricanes and storms cause disturbances to salt marsh vegetation (Burger and Shisler, 1983; Jackson et al., 1995; Valiela et al., 1998; Boose et al., 2001; Costanza et al., 2008; Meert and Hester, 2009; Morton and Barras, 2011). Hurricanes can increase dispersal of wrack on the upper marsh, thus causing damage to plants and at times facilitating colonization by new species (Tolley and Christian, 1999; Bart and Hartman, 2003; Silliman and Bertness, 2004; Lonard et al., 2012). Storms can also transport and deposit anthropogenic materials on top of salt marsh vegetation, potentially crushing and shading the above ground plant shoots (Valiela et al., 1998; MacLennan, 2005). In this way, human influence (e.g., development and building of structures vulnerable to destructive forces) and storms can have a synergistic and negative effect on salt marshes through deposition of debris.

With the increase of residential development along coastal regions, more anthropogenic debris (e.g., wood from buildings and docks, plastics, tires) is entering marine environments (Niedowski, 2000; Worm et al., 2006; Widmer and Hennemann, 2010; Uhrin and Schellinger, 2011; Viehman et al., 2011; Tibbetts, 2015). In addition, derelict fishing gear can be a major source of debris in marine habitats (e.g., NOAA, 2016 and references therein; Scheld et al., 2016). The objective of the present research was to examine the impact that large marine debris (wooden docks dislodged by storms) has on the salt marsh vegetation. Specifically, this study explored how vegetation responded after the removal of such debris and if recovery of these disturbed areas followed the typical pattern of salt marsh succession.

Removal of marine debris through managed clean-ups involving volunteers has been successful in preserving and restoring coastal environments (Niedowski, 2000; Gedan et al., 2009; Uhrin and Schellinger, 2011; Critchell et al., 2015). Many managed clean-ups focus on removing small debris (e.g., plastics) on beaches but other initiatives include removal of large anthropogenic debris (such as derelict crabbing pots and other fishing gear), which have been shown to have positive ecological and economic impacts (NOAA, 2016; Scheld et al., 2016). Less is known about the impacts of removing large pieces of debris from marshes and how to best manage clean-ups in this habitat (Uhrin and Schellinger, 2011; Viehman et al., 2011; Driedger et al., 2015; Lee and Sanders, 2015). Therefore, the present study also tested two factors that should be considered when planning a salt marsh clean-up concentrating on large debris to minimize negative impacts: 1) seasonal timing of debris removal and 2) effects of trampling during removal of debris.

The timing of debris removal was tested because it is unknown whether this factor affects the recovery of salt marsh plants. This study examined whether there was a difference in salt marsh recovery when debris was removed in the early spring (March) versus the mid fall (October). Hurricane season in the western Atlantic coast is from June–November, therefore it is likely that more marine debris, and large debris in particular, is deposited on salt marshes during the fall season (Changnon, 2009).

Ecological succession may be affected by the timing of debris deposition on salt marshes, the timing of clean-ups, and on whether recovery of plants is primarily from seeds deposited during the prior growing season, longer-lived seed banks, or rhizomes. If marine debris is deposited during the fall season and recovery is predominately via seeds from the growing season, then it is possible that delaying debris removal until spring of the following year would delay recovery by preventing colonization of the debris removal sites by seeds. If recovery is predominately via seed banks, then spring removal could lead to a slower recovery due to early season shading and compaction of marsh sediment as a result of the clean-up process. Lastly, if the recovery is predominately via rhizomes then, fall/spring removal plots would likely not show a difference in plant recovery. Rhizomes can stay viable underground for many years even after the death of the above ground biomass, therefore, permitting regrowth of vertical shoots directly from the disturbed areas (Brueggeman et al., 1992). Previous studies of natural disturbances on salt marshes have shown that overall recovery is likely to be dominated by vegetative growth via rhizomes (after initial colonization of *Salicornia* spp.), but less is known about recovery following large debris removal and the consequences of the timing of that removal (Stalter, 1973; Bertness and Ellison, 1987; Bertness and Shumway, 1993; Crain et al., 2008). Examining the effects of timing of debris removal on vegetation recovery could ensure that future clean-ups in this region are planned to maximize beneficial impact.

The effect of trampling on the vegetation during clean-ups was tested to identify damage caused by the volunteers. Large animals that historically grazed on salt marshes had significant effects on the above ground vegetation due to trampling and loss of soil structure (Turner, 1987; Schröder et al., 2002). Impacts of trampling caused humans has been investigated in other marine habitats (Eckrich and Holmquist, 2000; Davenport and Davenport, 2006). However, the effects of human trampling on salt marshes is poorly known, although Martone and Wasson (2008) showed that the percent cover of native marsh plants declined at sites trampled by humans. This could be problematic if invasive species like *Phragmites australis* invade trampled spots because *P. australis* can kill native plants by reducing the available light, reduce habitats for birds, become a source of fire susceptibility, reduce recruitment of some marsh inhabitants, and create large mats of wrack that can create more bare spaces (Egan and Ungar, 2000; Noe and Zedler, 2001; Burdick and Konisky, 2003). Thus, studying the trampling effect of humans on the vegetation during salt marsh clean-ups will help in planning effective conservation efforts and minimizing damage.

Although research on restoration efforts involving salt marshes has been conducted (e.g., Casagrande, 1997; Wolters et al., 2008; Artigas et al., 2015), there are no studies quantifying recovery of eastern coastal salt marsh vegetation after clean-ups of large wood debris with anthropogenic origin. After Hurricane Sandy in 2012, a series of marsh clean-ups utilizing community volunteers were organized from 2013 to 2015 to remove debris from a salt marsh in Nassau County, NY. The main goal in the clean-ups was to remove the deposited marine debris without causing additional damage to the vegetation. The primary objectives of this study were to: (1) quantify the amount of debris removed and the area cleaned of debris; (2) compare growth of marsh vegetation in plots that had wooden debris removed to control plots that were not affected by debris; (3) compare the impact of removing the debris at different times of the year (spring removal vs. fall removal) and (4) quantify trampling effects on vegetation during clean-ups. Based on these findings, recommendations for the best strategies and supplies helpful for clean-ups of large debris on salt marshes are presented.

2. Material and methods

2.1. Study site

Research was conducted on the salt marsh at Lido Beach, New York (40°35′38.03″N, 73°36′51.28″W), along the southern side of Hempstead