Ecological Engineering 97 (2016) 381–388

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Short communication

Evaluating soil properties and potential nitrate removal in wetlands created using an Engineering With Nature based dredged material placement technique

Jacob F. Berkowitz[a,*], Lindsey Green[b,c], Christine M. VanZomeren[a], John R. White[c]

[a] Engineer Research and Development Center, US Army Corps of Engineers, Vicksburg, MS 39180, United States
[b] Audubon Nature Institute – Aquatic Center, New Orleans, LA 70118, United States
[c] Wetland & Aquatic Biogeochemistry Lab, Dept. of Oceanography & Coastal Sciences Louisiana State University, Baton Rouge, LA 70803, United States

ARTICLE INFO

Article history:
Received 22 April 2016
Received in revised form 22 July 2016
Accepted 5 October 2016

Keywords:
Wetland creation
Soil properties
Dredged material
Nitrate removal
Engineering With Nature
Atchafalaya River

ABSTRACT

Many waterways around the globe, including those in southern Louisiana, require periodic dredging to maintain navigability in channels, rivers, and at ports. Traditionally, dredged materials are deposited in confined disposal facilities, relegated to deep open water disposal, or used as fill material to build wetlands. Over the past 15+ years, dredge material from the Atchafalaya River was strategically placed up-river of a small, natural shoal, located mid-channel, resulting in the creation of a wetland exhibiting many structural characteristics of the naturally occurring riverine wetlands within the basin. This construction practice adheres to Engineering With Nature (EWN) concepts which utilize natural processes to produce maximum benefit for navigation, while lowering economic costs and improving habitat features. The current study determined soil physical, nutrient, and biogeochemical properties at the EWN wetland and compares these characteristics to values observed at a traditional dredge shoreline material placement wetland (TDMP), essentially examining the effect of construction technique on soil biogeochemical properties. Soil total carbon and nitrogen at EWN continued to accumulate with time; however, TDMP exhibited a significantly higher degree of soil formation as indicated by lower bulk density, and higher soil organic matter, carbon, and nitrogen. Despite the observed differences, rates of potential nitrate removal and microbial biomass nitrogen did not differ between wetlands, suggesting that the nature based construction technique resulted in nutrient cycling and nitrate removal capacities equivalent to traditionally constructed dredged material wetlands in the region.

Published by Elsevier B.V.

1. Introduction

The geographical extent of wetlands continues to decrease at national and regional scales, including major wetland losses across southern Louisiana (Templet and Meyer-Arendt, 1988; Barras et al., 2003). Louisiana contains ~40% of the wetlands in the contiguous United States, and continues to exhibit rapid wetland losses representing nearly 80% of the total wetland losses in the lower 48 states (Day et al., 2000, 2007). Additionally, estimated wetland losses across the lower Mississippi Alluvial Valley exceed 74%; with only 2.8 of an original 10 million ha remaining today (King et al., 2006). Wetland losses in coastal Louisiana have been linked to a lack of sediment input and a high rate of relative sea level rise (Baumann et al., 1984).

The Mississippi and Atchafalaya Rivers drain roughly 41% of the contiguous United States, which includes the largest agricultural region in the nation (Goolsby et al., 1999). Increased fertilizer use has resulted in relatively high concentrations of bioavailable nitrogen (N) in the Mississippi and Atchafalaya Rivers through runoff (Schilling et al., 2012). Each year, these two rivers combine to deliver approximately 953,000 Mg of NO_3-N into the Northern Gulf of Mexico (BryantMason et al., 2013). The Atchafalaya River discharges ~18% of this or about 174,600 Mg of NO_3-N. Increased nutrient enrichment of coastal water, or eutrophication, is a leading contributor to the formation of a zone of hypoxia in the Gulf of Mexico each spring and summer (Rabalais et al., 2007). Wetlands can significantly reduce N loads from river water leading to improved water quality and a decrease in hypoxia in the Gulf of Mexico (Mitsch et al., 2001). However, the observed declines in wetland extent over time highlight the need for a continued focus on wetland restoration and creation (Berkowitz and White 2013; DeLaune et al., 2013; Theriot et al., 2013).

* Corresponding author.
E-mail address: Jacob.F.Berkowitz@usace.army.mil (J.F. Berkowitz).

http://dx.doi.org/10.1016/j.ecoleng.2016.10.022
0925-8574/Published by Elsevier B.V.

Wetland soils provide an ideal environment for the transformation of nitrate to N_2 gas through the facultative microbial respiratory pathway due to the combination of low O_2 availability and high organic carbon (C) content (White and Reddy, 2003; Valiela et al., 2000). Denitrification removes the bioavailable pool of nitrate from the system thereby improving the adjacent water quality. Estimates calculate restoration on the order of 10 million ha of wetland and riparian areas throughout the Mississippi River watershed would be required in order to remove enough nitrate from the river, primarily through denitrification, to eliminate hypoxia in the Gulf of Mexico (Mitsch et al., 2001). While this magnitude of wetland restoration may not be feasible, a few large-scale river reconnection projects have been implemented in the Louisiana coastal zone, (VanZomeren et al., 2012; DeLaune et al., 2013) as well as several wetland restoration projects utilizing dredged material.

The US Army Corps of Engineers (USACE) conducts dredging activities to maintain navigability of shipping channels in the lower Atchafalaya River, producing over 13 million cubic yards of material at a cost of $30 million dollars annually (Corbino, 2014). These dredging activities remove sediment from navigation channels, which is then available for beneficial uses, including wetland creation (Boustany, 2010). The beneficial use of dredged material is consistent with Engineering With Nature principles, a new USACE initiative, enabling more sustainable delivery of economic, social and environmental benefits associated with maintenance of water resources infrastructure (Bridges et al., 2014; Gerhardt-Smith and Banks, 2014; https://ewn.el.erdc.dren.mil/). Engineering With Nature concepts addressed through the current project include 1) the use of science and engineering to produce operational efficiencies supporting sustainable delivery of project benefits, and 2) the use of natural processes to maximize environmental benefits while enhancing the quality of the project. As a result, Engineering With Nature fits within the context of ecological engineering which has been practiced for over 30 years (Mitsch 1993, 2012); developing engineering practices that provide for human welfare while protecting or enhancing environmental goods and services (Bergen et al., 2001; Mitsch and Jørgensen, 2004).

During the 1990s, dredging within a section of the Atchafalaya River resulted in the construction of eight wetland development sites. Traditional dredged material placement (TDMP) areas are constructed by piping material from shoal areas adjacent to the navigation channel to shoreline areas, where current velocity is reduced and the dredged material settles in place with limited transport downstream. In some cases, dikes are constructed to restrict the movement of dredged sediments, encouraging dewatering and consolidation. The placement of dredged material in the region resulted in the creation of over 240 ha of wetland habitat (University of New Orleans, 2002). However, the potential areas available for placement of dredge material were nearly exhausted by 1999.

To meet the anticipated channel maintenance requirements for the future, the USACE evaluated three placement alternatives: 1) convert the wetland development sites into upland disposal areas, 2) open water placement of dredged material via a long-distance pipeline into the open waters of the Atchafalaya Bay, and 3) mounding of material at mid-river open water placement sites upriver of a small naturally forming submerged shoal. Environmental and cost concerns precluded the selection of alternatives 1 and 2. As a result, beginning in 2000 dredged material was strategically placed upriver from an existing underwater shoal to support construction of a mid-channel wetland in order to integrate requirements of USACE navigation mission with Engineering With Nature principles (Berkowitz et al., 2014).

This placement technique allows for the energy associated with river flow to re-work dredged material, mimicking natural sediment movement, deposition, and wetland formation. Since 2002, strategic placement of between 0.38–1.4 million cubic meters of sediment (0.5–1.8 million cubic yards) was conducted every 1–3 years, resulting in the development of a mid-river island, referred to herein as EWN (Fig. 1). While this activity may seem counterintuitive to USACE navigation protocols, the creation of an island directly adjacent to the navigation channel has the potential to decrease the cross sectional area of the river, thus increasing the river flow rate sufficiently to reduce shoaling and maintenance dredging requirements (Suedel et al., 2014).

The current study examines soil properties at EWN and compares observations with measurements collected at TDMP to determine if this construction practice resulted in differing soil properties including soil extractable NH_4-N and rates of potential nitrate removal, both important characteristics related to wetland nutrient cycling functions.

2. Study site location and methods

The EWN wetland (N 29°31′57.504”, W −91°16′28.7754”) occupies 35 ha located within the main channel of the Atchafalaya River, while the 23 ha TDMP wetland (N 29°32′53.1234”, W −91°15′33.9474”) is located adjacent to the shoreline. Both study areas are located 33 km south of Morgan City, Louisiana (Fig. 2).

Habitat classification followed Cowardin et al. (1979). The distribution of habitat types was determined using interpretation of aerial imagery with verification by ground identifications. Elevations were determined using Trimble R8 GNSS GPS receivers via Online Positioning User Service and Continuously Operating Reference Stations tied to a base station established onsite; estimated accuracy remained <2 cm. The water table elevation was measured in order to link the island observations to the Atchafalaya River stage gauge at Morgan City (USGS 07381600) and allow the determination of the period of inundation for each wetland and habitat type based on data from 2013.

During August 2014, soil cores were taken from four representative areas within each wetland habitat type on each island (aquatic bed, emergent, forested, and scrub-shrub). Push cores were collected using 7 cm diameter acrylic tubes to collect approximately the top 30 cm of soil. The cores were placed in a core rack, covered, and stored at 4 °C. Homogenized soil subsamples from the top 0–5 cm of each core were used to investigate soil conditions within the zone of highest microbial activity (Gardner and White, 2010). Analyses included particle size, soil organic matter content, bulk density, total carbon (TC), total nitrogen (TN), total phosphorus (TP), extractable NH_4-N and soluble reactive P (SRP), and microbial biomass N (MBN).

Particle size was determined using a Beckman Coulter LS 13 320 laser diffraction particle size analyzer (Eshel et al., 2004). Soil organic matter content determination followed the loss on ignition (LOI) method; dried ground samples underwent combustion at 550 °C in a muffle furnace for 4 h (Sparks, 1996). Dry weight bulk density was calculated from the total wet weight of the soil sample, corrected for moisture content, and divided by volume of the soil section. Total C and TN were measured on dried, ground soil samples using an Elemental Combustion System (Costech Analytical Technologies, Inc., Valencia, CA). Total P was quantified using the ashing-digestion method as described by Andersen (1976). Extractable NH_4-N and SRP were determined by a 2 M KCl extraction followed by filtering through a 0.45 μm Supor-450 membrane filter, acidified to a pH < 2, and stored at 4 °C until analysis using a SEAL AQ2 Automated Discrete Analyzer (SEAL Analytical, West Sussex, England; Methods 365.1; USEPA, 1993). Detection limits for NH_4-N and SRP were 0.012, and 0.005 mg L^{-1}, respectively. Microbial biomass N utilized the chloroform fumigation-extraction