

NUTRIENT STORAGE RATES IN A NATURAL MARSH RECEIVING WASTE WATER

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Abstract—Artificial wetlands are commonly used to improve water quality in rivers and the coastal zone. In most wetlands associated with rivers, denitrification is probably the primary process that reduces nutrient loading. Where rivers meet oceans, however, significant amounts of nutrients might be permanently buried in wetlands because of global sea-level rise and regional subsidence. We determined nutrient storage rates in the marshes adjacent to a minor stream to test the hypothesis that a natural wetland adjacent to Lake Pontchartrain (Louisiana) does not affect nutrient inputs to this estuary. Data from soil cores indicated that marshes store 240 t of N and 11 t of P each year. These data demonstrate that wetlands associated with rivers substantially modify nutrient transfer from terrestrial to aquatic habitats. Hydrologic data are being collected that can be used to determine what portion of the nutrient load of the river is buried in the marsh, and what portion of the nutrient load is discharged into the receiving basin.

INTRODUCTION

Artificial wetlands are now commonly used to improve water quality; long-term operational information exists for many full-scale projects (Kadlec and Knight 1986). Despite a growing body of data relating artificial wetlands and waste water, there have been few studies of the effects of natural wetlands on waste water (see Kadlec and Knight 1986 for a historical perspective). Those studies generally focused on denitrification, which converts nitrates and ammonia to nitrogen gas rather than on burial because, in most regions, burial is too slow to remove significant nutrients. In subsiding environments, however, burial might permanently store significant amounts of nutrients. Nutrient burial rates have been studied in natural wetlands in the Florida Everglades, North Carolina estuarine marshes, and in southwestern Louisiana (Craft and Richardson 1993, Craft and others 1993, Foret 1997). Nutrient storage rates in soil have rarely been studied in natural wetlands receiving waste water and never in wetlands of the Lake Pontchartrain Basin, Louisiana. This is surprising given the large public concern regarding eutrophication in the lake and the relatively rapid subsidence of coastal Louisiana.

A lack of information on nutrient storage rates in wetlands underlies public and professional controversy regarding the benefits of water-quality regulations, wetland protection and restoration activities, and the benefits of introducing nutrient-rich water to estuarine marshes. Relationships among nutrient sources and rates and nutrient sinks and rates need to be better understood in wetland nutrient dynamics in general, and in Lake Pontchartrain, in particular. We tested the hypothesis that a natural wetland at the mouth of a freshwater stream emptying into Lake Pontchartrain does not affect nutrient inputs into the lake.

STUDY AREA

The study was conducted on the northern shore of Lake Pontchartrain in a naturally occurring marsh that predates

the earliest aerial photographs. Lake Pontchartrain is a large (the diameter is approximately 60 km) estuary in southeastern Louisiana that receives freshwater from numerous rivers and streams on its northern shore and sea water from a tidal pass at its eastern end. The marsh studied was located at the mouth of Salt Bayou, which carries freshwater from the Pearl River to Lake Pontchartrain. The marsh, which lies on a tributary (Salt Bayou) to Lake Pontchartrain, was classified as brackish and intermediate (Chabreck and Linscombe 1978). Construction of railways and highways across Salt Bayou reduced freshwater input from the Pearl River into the marsh in the mid-1950s. That reduction in freshwater inflow is believed to have contributed to subsequent conversion of marsh to shallow open water. Since 1956, 2,485 ac of marsh have converted to shallow, open water; 3,438 ac of marsh remained in 1990 (NRCS 1997).

A canal adjacent to Fritchie Marsh, the W-14 Canal, carries urban runoff and tertiary-treated domestic sewage from the community of Slidell to Lake Pontchartrain. Most water in the W-14 Canal discharges directly into Lake Pontchartrain, but some leaves the canal and flows through the Fritchie Marsh before rejoining the W-14 Canal and then discharging into Lake Pontchartrain. A Coastal Wetland Planning, Protection, and Restoration Act (CWPPRA) project is scheduled for construction in the Fritchie Marsh by the end of 1999. That CWPPRA project will increase the amount of water flowing from the W-14 Canal into the Fritchie Marsh. The intent of that freshwater introduction is offset by the loss of freshwater inputs from the Pearl River caused by the railways and highways crossing Salt Bayou that were constructed earlier this century. The Louisiana Department of Natural Resources (DNR) will collect data that can be used to estimate the effect of the W-14 Canal water on vegetation and marsh loss in the Fritchie Marsh (Department of Natural Resources 1996).

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METHODS

Marsh Soil

One data set was collected to quantify long-term nutrient storage rates in Fritchie Marsh. Nutrient storage rates were determined from the accretion rate of soil and the nutrient content of soil in the marsh. This is possible because new soil continually forms on the surface of estuarine marshes; this process is called vertical accretion and is essential because global sea-level rise and subsidence would otherwise drown estuarine marshes (Mitsch and Gosselink 1986: 178–181). A pair of cores was collected from DNR vegetative monitoring station 22; another pair of cores was collected from DNR vegetative monitoring station 1. Station 1 was at the northern, upstream end of the study area; station 22 was at the southern, downstream end. The cores were returned to the lab, sectioned, weighed, oven-dried, weighed, and crushed. Bulk density of each section was calculated. Vertical accretion since 1963 was determined with the ^{137}Cs dating technique (DeLaune and others 1978). Activity of ^{137}Cs was determined with an Ortec GMX series Gamma-x-high purity, N-type germanium coaxial photon detector system. Vertical accretion rates were compared to regional estimates of subsidence to determine if there was a vertical accretion deficit. Vertical accretion deficits are often the mechanism by which sediment starvation and rapid subsidence cause wetland loss in coastal Louisiana, e.g., Nyman and others 1993.

The gross material accumulation rate, i.e., the accumulation of mineral sediments as well as organic matter, was calculated for each core from the bulk density of soil samples overlying the 1963 marsh surface. The accumulation rate of mineral sediments and organic matter was similarly calculated from the bulk density and ash content of each section overlying the 1963 marsh surface. The accumulation rate of nitrogen (N), carbon (C), and phosphorus (P) was similarly calculated from the bulk density and the nutrient content of soil overlying the 1963 marsh surface. Carbon and nitrogen content were determined by ignition in a Carlo-Erba Elemental Analyzer equipped with a thermoconductivity detector. Phosphorus content was determined following acid digestion using Parson's colorimetric analysis (Parsons 1984).

Water Quality

A second data set was collected to compare changes in nutrient concentration in waters that empty directly into the lake to changes in nutrient concentration in waters that flow through the Fritchie Marsh before emptying into the lake. Data were collected on two transects that originate at a common point in the W-14 Canal and terminate at a common point in Lake Pontchartrain. However, one transect runs through the W-14 Canal, and the other runs through the Fritchie Marsh. Selecting sites for collecting water samples was more complicated than selecting sites for soil samples. We had planned to collect water samples at DNR sites simultaneously with DNR personnel. However, it was impossible to sample along the W-14 Canal from the DNR airboat because of numerous low bridges that cross the canal. Alternate transportation was arranged after ULL purchased a boat for research. Using a small boat rather than an airboat reduced the area accessible for collecting water

samples and increased time required to collect samples because shallow water areas cannot be crossed. Collecting water samples was further delayed because the landowners forbade sampling during waterfowl hunting season.

Both transects had 10 sampling stations. At each station, a surface water sample was collected. Salinity and conductivity were measured with a YSI model 6920 salinometer (Yellow Springs, Ohio) simultaneously with the collection of each water sample. Nutrient concentration was determined on the unfiltered water samples. Total N and P content were determined using Parson's colorimetric analysis (Parsons 1984). Changes in nutrient concentration resulting from dilution with lake water were differentiated from nutrient uptake with mixing diagrams, i.e., ionic ratios (Day and others 1989: 81–85).

RESULTS

Marsh Soil

Average bulk density was greater at the northern site than at the southern site. The greater bulk density at the northern site incorrectly suggested that more material is introduced into Fritchie Marsh from the W-14 Canal than from Lake Pontchartrain. However, examination of density profiles with depth suggests that recently formed, surface soils were similar at the two sites. Thus, the northern and southern sites currently appear to be storing more similar amounts of material than the average bulk density suggests.

Accretion in Fritchie Marsh was slightly less than the average for brackish marshes in the Mississippi River Deltaic Plain (0.72 cm per year) (Nyman and others 1990). The more rapid average accretion in the entire Mississippi River Deltaic Plain than in the Fritchie Marsh results from the more rapid subsidence rate elsewhere in the Mississippi River Deltaic Plain (approximately 1.0 cm per year) (Penland and others 1990).

Accretion rates within sites were almost identical, but the two sites differed greatly. Accretion at the northern site was 40 percent slower than at the southern site. Accretion at the northern site is similar to estimates of subsidence on the northern shore of Lake Pontchartrain, which is estimated at 0.45 cm per year (Penland and Ramsey 1990). However, it is difficult to reconcile the rapid accretion at the southern site with the slow subsidence reported by Penland and Ramsey (1990). It is also unusual for accretion rates to vary so much within such a small area, e.g., Nyman and others 1990, Nyman and others 1993. The large difference between northern and southern sites suggests that a shallow, active fault runs through Fritchie Marsh. Such faults are common in coastal Louisiana in general and around Lake Pontchartrain. Lopez (1991) examined seismic data and reinterpreted the location of the Baton Rouge/Denham Springs fault system and concluded that the fault lay farther south than previously believed and positioned it such that it would bisect the Fritchie Marsh. Our findings support Lopez's (1991) conclusions regarding the position of that fault system. Lopez (1991) also concluded that the fault system was active and responsible for a 6-inch offset on the State Highway Bridge 11 crossing eastern Lake Pontchartrain. The tremendous difference in accretion rates between the

northern and southern sites that we observed support Lopez's (1991) conclusion that the fault system is active, although different faults within the fault system would be required to produce offset in accretion in the Fritchie Marsh and the offset in the highway bridge. Whereas this active fault may contribute greatly to wetland loss in the Fritchie Marsh, it also increases the potential for burial of nutrients in the marsh.

Gross material accumulation was 20 percent slower at the northern site than at the southern site. The faster accumulation rate at the southern site results from the more rapid vertical accretion induced at the southern site by the fault. Extrapolated to the entire area, it appears that the 1,040-ac Fritchie Marsh restoration site stores slightly over 13,660 t of material annually. Some of this material is organic carbon that is produced in the marsh, but the associated nutrients and sediments otherwise would be discharged into Lake Pontchartrain.

The material being stored in wetland soil at the Fritchie Marsh includes mineral sediments, organic matter, and the ecologically important elements C, N, and P. A significant amount of the nutrients N and P is being stored in the marsh soils, but the amount stored has decreased 48 percent since the 1950s because of the conversion of wetlands to shallow open water areas, which are assumed to be stable rather than accreting.

The N:P ratio of soil at the northern site was slightly higher than that at the southern site. Higher ratios indicate a greater potential for P availability to limit plant growth at the northern site, but the small difference between the sites may not be ecologically meaningful. These ratios appeared typical; they were similar to those reported for unmanaged, *S. patens* dominated marsh at Rockefeller Refuge (Foret 1997).

Water Quality Data

Nutrients were more concentrated in water in the W-14 Canal than in Lake Pontchartrain water. This situation is typical of estuaries in general (Liss 1976). For example, N concentrations in the Mississippi River generally average 3 to 4 parts per million (ppm) but drop rapidly to approximately 1.0 ppm soon after entering estuarine marshes (Lane and others 1995). Phosphorus in the Mississippi River also drops rapidly soon after entering estuarine marshes from approximately 0.4 ppm P in the river to approximately 0.2 ppm P after entering estuarine marshes. Nutrient concentrations in the W-14 Canal were less than those reported for the Mississippi River (Antweiler and others 1995, Lane and others 1999) and did not exceed 1.5 ppm N (108 $\mu\text{mole N/l}$) or 0.5 ppm P (16 $\mu\text{mole P/l}$).

A simple comparison of nutrient concentrations between water in the W-14 Canal and the marsh incorrectly suggests that the marsh was removing nutrients when the water samples were collected. Proper evaluation of the water-quality data indicates that the low-nutrient water in the marsh was actually low-nutrient, high-salinity water introduced from Lake Pontchartrain at an earlier date and, subsequently, stored in the marsh. Thus, the low-nutrient, high-salinity water in the marsh interior indicates at least

periodic hydrologic isolation of the marsh interior. The isolation apparently results from a lack of inflow from the W-14 Canal at the northern (upstream) end of the marsh, and possibly from high-water levels in the W-14 Canal that inhibit drainage of the marsh at the southern (downstream) end. The proposed restoration project should introduce more water through the marsh and thereby reduce the hydrologic isolation that the marsh currently experiences. It could not be determined if the failure to detect nutrient uptake with the water-quality data resulted from a true lack of uptake or from an inability of the technique to detect real differences.

Water in the W-14 Canal had a very low N:P ratio relative to N:P ratio in the marsh interior. The difference in N:P ratio resulted from 7-fold lower P concentrations rather than greater N concentrations. The N:P ratio of the W-14 Canal was similar to ratios in P-rich waters entering the Florida Everglades; the N:P ratio of the marsh interior was similar to ratios in unimpacted portions of the Florida Everglades (Reddy and others 1999). The N:P ratio in water samples suggests that P availability limits algae production in the marsh interior but not the W-14 Canal. Increasing input of P-rich water to the marsh should increase algae production, which might increase the formation of recalcitrant, organic-P compounds.

CONCLUSIONS

Data from four cores indicated that the marshes at the Fritchie Marsh store significant amounts of N and P each year. Collectively, the marshes remove 240 t of N and 10.9 t of P from the Lake Pontchartrain estuary each year. While significant, these rates are only 42 percent of the removal rates that existed before extensive wetland loss that occurred since 1956.

Nutrient storage in wetland soils was faster at the southern end of the marshes despite nutrient concentrations being lower because soil formation there is more rapid. More rapid soil formation at the southern end of the marshes appears to result from an active fault system previously reported in the area. Additional data are needed to characterize nutrient storage given the great difference between the northern and southern ends of the study area.

Water-quality data indicated limited water exchange between the marsh interior and the adjacent water channels. Water-quality data failed to indicate nutrient uptake when mixing diagrams were used, but N:P ratios in water samples indicated that algae production in the marsh interior was P-limited when samples were collected.

The imminent wetland restoration project should increase nutrient storage rates in marsh soil and may increase the production of recalcitrant, organic forms of P that can be stored in bottom sediments of shallow, open-water areas common in the marsh interior. The imminent wetland restoration project should also reduce the hydrologic isolation of the marsh interior and may thereby reduce plant stress, increase plant production, and increase nutrient burial in soil.

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