CSAP Project Narrative

Title of Project: The Relative Contribution of Plant Uptake vs Denitrification of Nitrate in Water Quality Improvement from Sediment River Diversion Operations

Introduction to the Problem: River reconnection (sediment diversions) to coastal basins is one restoration project type being implemented in Louisiana to combat the large coastal land losses due to coupled subsidence and sea level rise (White et al., 2019). The diversions will deliver a sediment subsidy from the "muddy" Mississippi River in the way of suspended sand, silt, and clay material. However, the river water will carry relatively high concentrations of nitrate during the springtime flood at the same time the diversions are planned to be operated. Wetlands are effective at removing excess nutrients, especially nitrogen, by both assimilation into plant biomass and by gaseous loss by denitrification. Over 95% of the bioavailable N pool in the Mississippi River is in the NO_3^- form (White et al., 2009). While we now have research recently conducted on the spatial distribution of denitrification rates across the diversion influence area (Pinzon, 2003), what is still relatively unknown is, "How much of this N will be taken up by the macrophytes?". There is a single study conducted in a *Spartina patens* marsh in Breton Sound which give us some idea of the relative fate of surface water nitrate (VanZomeren et al, 2012). The authors found that 65% of surface water NO_3^- was removed by denitrification, with 27% of nitrate incorporated into the aboveground biomass with the remaining 8% incorporated into the soil, roots and microbes combined (Figure 1; VanZomeren et al, 2012). This study was conducted as a batch study instead of a more representative flow-through system as we would expect for a diversion and with no temperature control. In addition, for the Mid-Barataria Sediment Diversion influence area, there will be fresh, brackish, and salt marsh plant species with the opportunity to intercept the river NO_3^-. A study from Davis Pond used the ~^{15}N of the plant material and soil to identify the proportion of the wetland affected from river nitrate (Spera, 2019). However, as a field study, there was no mass balance possible and therefore little utility for spatial modeling. Consequently, the single species plant uptake data we currently have is inadequate to predictively model with much accuracy, the resulting water quality changes, given the range of marsh plant species present in the receiving area of the Mid-Barataria sediment diversion.

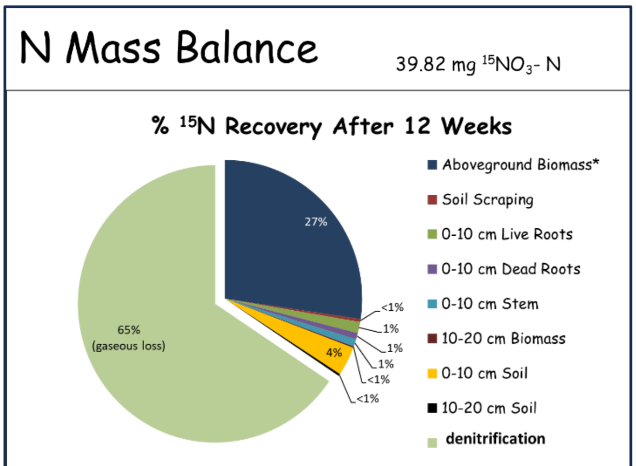

Figure 1. Relative Distribution of ^{15}N-NO_3 pools added to vegetated, Spartina patens marsh.

Research Goal and Objectives: The research goal is to reduce uncertainty in predictive ecosystem impact water quality modeling by determining the plant uptake rates of NO_3^- in order to provide the state of Louisiana and its citizens more accurate predictions for potential impacts of diversion operation on water quality. This water quality is inexorably tied to LA's economically important coastal fisheries and recreation by its citizens. Research objectives include 1) Collect representative vegetated soil plugs from across the freshwater − saltwater continuum in Barataria Bay; 2) Conduct a $^{15}N\text{-}NO_3$ loading experiment to mimic the planned sediment diversion operation duration; 3) Partition the planted soil columns into above and belowground biomass, as well as unrooted soil to determine N partitioning.; 4) By mass balance, determine the relative fate of surface water nitrate in vegetated marsh.

Research Methodology: Stable isotopic techniques (^{15}N) have been used extensively as important tools in determining the ultimate fate of N additions to a wide range of ecosystems, specifically allowing us to identify N transformation pathways including immobilization, nitrification, and denitrification processes (Barraclough, 1991). Consequently, the treatment level of nitrate will be chosen based on the range of concentrations within the Mississippi River during spring flood (Lane et al., 1999). The nitrate used will be 99% enriched atom $^{15}N\text{-}NO_3$ in order to differentiate the surface water N from the natural ^{14}N of the soil (Cambridge Isotope Laboratory, Andover, MA). In concert with the student and with consultation from CPRA and others, we will determine the length of time and the target inflow concentration for each plant community based on best available information. Representative, quadruplicate vegetated plugs will be collected from the field along the salinity gradient and returned to a greenhouse at LSU (Figure 2). Instead of a batch study which was previously done for Breton Sound, we will use a series of pumps to continuously feed water containing $^{15}N\text{-}NO_3$ at the target concentrations to the experimental units. The cores will be set in a water bath that will be controlled for the expected temperature of the river water during the springtime flood.

Figure 2: Example of vegetated plugs returned to greenhouse.

The cores will have a hole drilled to allow the pumped water to exit the cores maintaining a constant water column height. The inflow and outflow water will be analyzed colorimetrically for NO_3^- to determine the net retention in the vegetated units (USEPA, 1993). At the end of the N loading study, to approximate the length of time the sediment diversion is expected to operate, a mass balance sampling will be conducted to determine the quantity of surface water $^{15}N\text{-}NO_3$ was taken up by the various vegetation types. This fractionation will include sampling the soil, the live roots, dead roots, and live and dead aboveground biomass in each experimental unit (Table 1; after VanZomeren et al, 2012). Samples will be analyzed for ^{15}N content using a Europa 20-20 CF-IRMS interfaced with the Europa ANCA-SL elemental analyzer. In the end, a mass balance will provide the amount of $^{15}N\text{-}NO_3$ lost by gaseous processes, primarily denitrification. This

Table 1. List of experimental components.

Mass Balance Components
- Live aboveground
- Dead aboveground
- 0-10 cm live roots
- 0-10 cm dead roots
- 0-10 cm stem
- 0-10 cm soil
- 10-20 cm live roots
- 10-20 cm dead roots
- 10-20 cm stem
- 10-20 cm soil
- soil scraping (for algae)

information will be shared with the modelling community to then allow a more robust prediction of water quality changes related to sediment diversion operations.

Importance to CPRA and the Coastal Master Plan: This research is applicable to the restoration tool of Sediment Diversions that is clearly laid out in the 2017 Master Plan at a cost of 5 billion dollars to implement, although we now recognize the actual costs to be somewhat higher. These sediment diversions will affect large areas of coastal wetlands by providing a sediment subsidy over a basin-wide scale. This concept was borne out in research done within the Wax Lake Delta, which found that winter storms force sediment up on the vegetated marsh due to cold front patterns (Roberts et al, 2015). There has been modeling of where the diversion water goes and modeling to determine the water quality change in the basin. The model was using a single denitrification rate, while our recent research determined the denitrification rates is variable depending upon if the water is in the vegetated marsh, over eroded marsh or exposed to open bay sediments (Pinzon, 2023). What is missing now is an understanding of the nitrate uptake rate across the fresh, brackish and saltmarshes which will interact with the river nitrate. There exists but a single study which found that 65% of surface water nitrate was removed by denitrification, with 27% of nitrate incorporated into the aboveground biomass with the remaining 8% into the soil, roots and microbes combined (VanZomeren et al, 2012). The location was in a brackish *Spartina patens* dominated marsh in Breton Sound. Since the Mid-Barataria Sediment Diversion will impact fresh marsh, brackish marsh and salt marsh, a study is needed to examine uptake by this range of vegetative communities (Figure 3). In addition, this previous study was not done at a controlled, representative temperature and therefore rates of nitrate uptake vs denitrification might not be applicable for the operation of a sediment diversion whose timing is linked to maximum sediment load that is typically seen on the rising limb of the first spring flood pulse (Peyronnin et al, 2017). This data is critical to accurately predicting sediment diversion impacts to the surface water quality of Barataria Bay. This research would close the loop on the nutrient budget of the basin with sediment diversion operation and allow more accurate predictive modeling for the state of Louisiana as well as the citizens of Louisiana. These predictions will have applicability to the extensive coastal fisheries community, recreational users as well as informing overall environmental condition. Additional details regarding experimentation will be worked out in consultation with the selected student, in order to provide the Masters student with an opportunity for input and a sense of ownership for this proposed research.

Figure 3. Study area depicting the Mid-Barataria Bay Sediment diversion influence area, marsh type locations (LA TIP, 2023).

Reference

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