Plant Performance and Nutrient Effects of Conventional and Sustainable Fertilizers in Seagrass Restoration

Rendimiento de la Planta y Efectos de los Fertilizantes Convencionales y Sostenibles en la Restauración de Pastos Marinos

Performances des Plantes et Effets Nutritifs des Engrais Conventionnels et Durables dans la Restauration des Herbiers Marins

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EXTENDED ABSTRACT

Introduction

Fertilization is a popular and relatively inexpensive technique used to improve seagrass restoration success. Phosphorus nutrient enrichment has been proven to have positive effects on seagrass above and belowground biomass in P limited systems (Armitage and Fourqurean 2015). Ecosystem succession appears to be kickstarted by the additional nutrients in the short and long term (Bourque and Fourqurean 2014, Armitage, Frankovich, and Fourqurean 2011). Harnessing these phenomena could be valuable in seagrass restoration, especially in seagrass scars, where the fill may not have the nutrients required to facilitate efficient recovery of the seagrass system. However, the use of commercially available fertilizers (i.e. osmocote) or bird roosting stakes may result in variable levels of nutrients, over-fertilization, and pollution of the surrounding environment. A slower dissolving fertilizer may reduce nutrient pollution while still providing resources toward seagrass growth and survival.

To increase the recovery rate and thus minimize the negative feedback of temporal sea grass destruction, as well as to enhance ecosystem resilience, we suggest the application of struvite. Struvite (magnesium ammonium phosphate) is a by-product of wastewater treatment processes, obtained in separated, side-stream sludge management processes. It is a high-quality, slow-release fertilizer, free of heavy metal contamination (Talboys et al. 2016). Struvite is poorly soluble in water but will more readily release P in the presence of organic acids exuded from roots, making it an ideal fertilizer for direct plant uptake (instead of diffuse release into surrounding water) (Lopez-Bucio et al. 2000). The application of struvite for restoration purposes would also support a more sustainable management of phosphorus resources through the increased use of re-used wastewater nutrients (Mayer et al. 2016). To determine the effectiveness of struvite in seagrass restoration, we conducted a mesocosm study comparing this fertilizer to the commercially available fertilizer osmocote.

The objectives of the mesocosm experiment are:

i) To find if differences in the growth of seagrass occur due to the addition of struvite vs osmocote in mesocosms,and
ii) To determine shifts in sediment and porewater nutrients caused by the introduction of phosphate and struvite in plots with and without seagrass.

We hypothesized the following:

i) That seagrass in plots fertilized with struvite would have increased performance (identified via shoot count) compared to plots fertilized with osmocote, and
ii) Struvite would dissolve at a slower rate than osmocote (determined by measuring porewater total phosphorus).

Methodology

To minimize confounding variables and investigate biogeochemical processes related to nutrient fertilization, a mesocosm experiment was implemented at the Whitney Laboratory of Marine Biosciences in St. Augustine, FL (Figure 1). Inflow was taken from offshore St. Augustine and entered through a lime rock and activated charcoal biofilter, reducing contamination of the surface water. Filtered water entered a 6.5 m mesocosm and was kept around 1 m deep, to emulate the donor environment and to reduce confounding variables like rainfall. The experiments were based on the methods explained in the propagation guide for *Halodule wrightii*, prepared by the University of Southern Mississippi (Biber et al., 2013). Seagrass was collected directly from donor sites off St. Martins Marsh Aquatic Preserve. Shoots were removed from sediment and transplanted into plastic containers (10 cm depth), buried in approximately 5 cm of shelly sand taken from the local St. Augustine area (rinsed to reduce organics and residual nutrients). Two separate experiments were conducted in the summer and fall of 2018. The first consisted of six different sampling plots: bare sand with and without nutrients (phosphate/struvite), and seagrass with and without nutrients. In total there were 30 replicates, with each control having four replicates, each seagrass treatment containing six and each sediment treatment containing four. Nutrient treatments were fertilized with 0.5 mg P/g DW, half of what was considered "lightly fertilized" according to Peralta et al. 2003 in a separate seagrass fertilization study. Each seagrass treatment had exactly three individuals, each with five shoots. The experiment was conducted for 60 days. During this period, total phosphorus levels were excessively high, upwards to over 100 mg/L in the osmocote treatments and 5 mg/L for struvite. Therefore, a second experiment was conducted consisting of multiple lower doses of struvite and osmocote. For struvite, 0.050, 0.025 and 0.0125 mg P/g DW doses were implemented. For osmocote, 0.025 and 0.0125 mg P/g DW doses were used. Fertilized controls had a 0.025 mg P/g DW dose of osmocote and struvite.

In both experiments, seagrass shoots per plot were counted approximately every 10 days for shoot counts, and a brief growth study was also conducted. Surface water was sampled for temperature, salinity, and flow rate. Surface and porewater were filtered (0.45 microns) and measured for total organic carbon, total nitrogen, and total phosphorus. At the beginning and end of the experiments, plants were collected, oven dried and weighed (above ground vs below ground). Tissues and sediment have been collected but need to be analyzed. All analyses were/will be conducted using methods from the Soil and Water Sciences Department's Wetland Biogeochemistry Lab. Treatment differences were tested using a Kruskal Wallis test as well as log transformed ANOVA and Tukey HSD.

Results

Mesocosm conditions in both studies appeared to be relatively stable. Temperature and salinity remained between 27 - 31° C and 33 - 38 ‰, respectively, during the periods sampled (between 9 am and 3 pm). The residence time was variable at 0.5 - 2 days, due to a limited and shared saltwater supply. However, the mean TP of surface water was 0.035 ± 0.001 mg/L (0.029 mg/L excluding a day of low inflow). Based off the above data, we can infer that the level of flow was great enough to prevent significant cross contamination of the plots studied, as well as preventing significant swings in temperature and salinity that could stress the plants.

During the first experiment, increases in shoot counts occurred one month after transplantation (Figure 2). The propagation guide for *Halodule* states that transplant shock may affect the plant for 1-2 months, those results are consistent with the results of this study. Seagrasses in struvite fertilized plots had significantly higher amounts of shoots than the controls and osmocote ($p > 0.02$). Porewater total phosphorus data revealed significant differences between osmocote plots and others ($p > 0.005$). The average range of concentrations for osmocote porewater plots ranged from to 19.6 ± 2.08 to 136 ± 7.85 mg/L, over ten times higher than struvite plots, which ranged from 0.34 ± .038 to 2.43 ± 0.31 mg/L. Controls (both bare sand and seagrass) ranged from 0.17 ± .006 to 0.29 ± 0.04 mg/L. Other results/statistical analyses are pending. However, future statistical analyses would include correlations between shoot counts and nutrients, in addition to Wilcoxon signed rank tests to compare plots over time.

Results from the second experiment are currently under investigation. Preliminary results found that seagrasses displayed growth, but no clear differences have been determined between osmocote and struvite shoot counts. This may be due to the planting occurring at the end of the growing season (ends typically in September, Dr. Osborne, personal correspondence). However, we still expect seagrass in medium and high struvite treatments to

Figure 1. Deployment of the first mesocosm experiment

perform to a degree comparable or superior to equivalent osmocote plots, based off the higher relative dissolution rate of osmocote determined in the first study. For the low dosage (1/40th of the last study), osmocote may perform better than struvite by providing a larger pool of nutrients to the plant. Finally, we expect the seagrass tissue samples from both experiments to reflect the environment they were exposed to, with osmocote plots having higher concentrations of phosphorus and nitrogen than the other controls/ treatments.

Conclusions

Our study suggests that struvite is a potentially superior fertilizer for seagrass restoration projects, being less soluble than osmocote while still improving seagrass health. Differences in porewater concentrations in the first experiment likely reflects higher osmocote solubility. Osmocote treatments may have been stressed from the degree of nutrients dissolving at once; preliminary tests of total dissolved nitrogen levels were also high. Future research will measure sediment and tissue samples for nutrient presence and uptake, and test both fertilizers in a seagrass scar restoration study.

KEYWORDS: Seagrass, restoration, fertilizer

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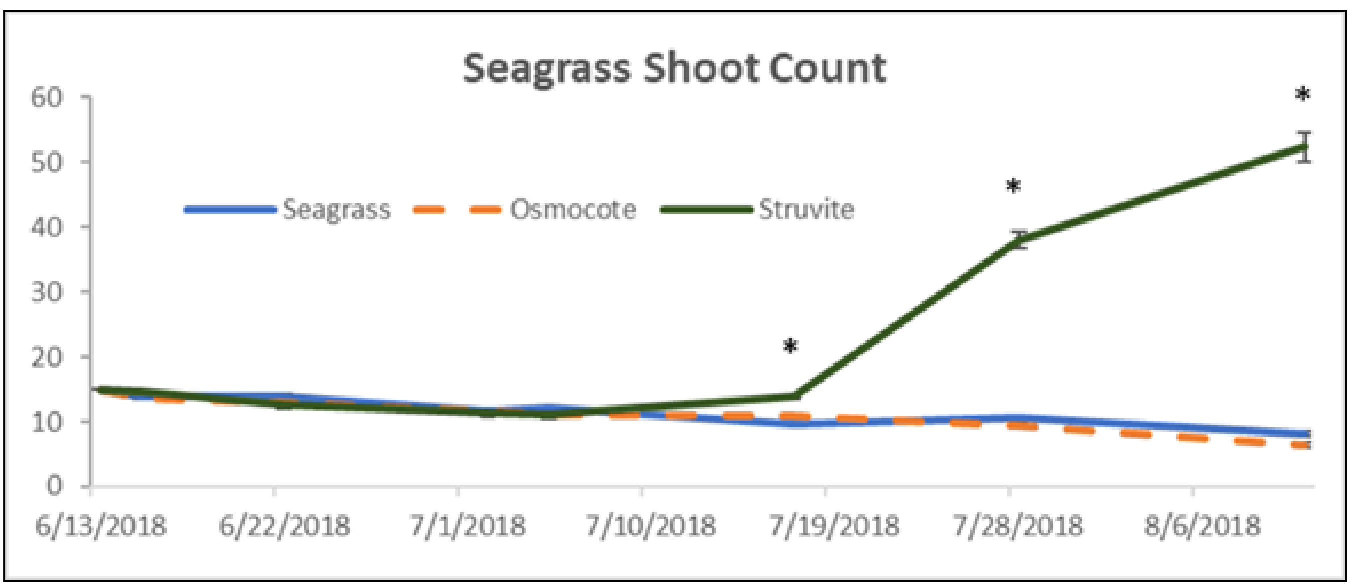

Figure 2. Shoot counts from the first mesocosm experiment. The * marks $p < 0.05$.