The Effect of Simulated Green Turtle Grazing 0n *Thalassia testudinum* Productivity, Benthic Community Composition, and Stingray Feeding Behavior

El Efecto del Pastoreo por las Tortugas Verdes Simulado en la Productividad de *Thalassia Testudinum*, la Composición de la Comunidad Bentónica, y la Búsqueda de Comida por las Rayas

L'influence du Broutage Simulé de Tortues Vertes sur la Composition de la Communauté Benthique, la Productivité des Herbiers Marins et la Recherche de Nourriture des Raies Pastenagues dans un Environnement Soumis à un Fort Ruissellement

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EXTENDED ABSTRACT

Introduction

Green turtles (*Chelonia mydas*) once played an important role in structuring Caribbean seagrass ecosystems, but today that role has been diminished due to its overexploitation, which has reduced Caribbean abundance to only 0.33% of pre-Colombian levels (McClenachan et al. 2006). Reduced *C. mydas* grazing in Caribbean seagrass beds has implications for the productivity (Zieman et al. 1984, Moran and Bjorndal 2005, Molina Hernández and Van Tussenbroek 2014, Holzer and McGlathery 2016) and benthic community composition (Molina-Hernández and van Tussenbroek 2014) of these habitats. Caribbean seagrass productivity has shown variable responses to grazing leading Fourqurean et al. (2010) to theorize that seagrass productivity should respond favorably to grazing when the energetic benefits of reduced self-shading are greater than the energetic costs of having to replace lost biomass. Holzer and McGlathery (2016) proposed that grazing should enhance seagrass production when seagrasses are not limited by phosphorous and to reduce seagrass production when plants are phosphorous-limited. These explanations can be combined to theorize that seagrass production should be enhanced by grazing when the energetic benefit of reduced self-shading is greater than the energetic cost of replacing lost biomass and plants are not phosphorous limited, but grazing should be expected to lower seagrass production if plants are phosphorous limited or if the cost of replacing lost biomass is greater than the benefit of reduced self-shading. To assess how the lack of grazing may have affected these variables in Bocas del Toro, Panamá we conducted a 168-day simulated grazing experiment to assess benthic community and seagrass productivity under varying levels of grazing pressure.

Methods

Highly grazed (HG), lightly grazed (LG), and ungrazed (UG) plots were established in *Thalassia testudinum* dominated beds on Isla Colón, Bocas del Toro, Panamá (9.4048° N, 82.2692° W). Five 2 x 2 m plots were established for each treatment. Green turtle grazing was simulated by cutting seagrass leaves to within 5 cm of the sediment surface. HG plots were "grazed" once every two weeks, LG plots were "grazed" once every four weeks, and UG plots were never artificially grazed. During the 168-day experiment, HG plots were "grazed" 12 times and LG plots were "grazed" 6 times.

Seagrass productivity was assessed using Zieman's (1974) shoot marking technique where shoots were pierced near the green/white interface and then allowed to grow for seven days. After seven days, shoots were harvested and all growth above the marking scar was considered to be old growth while all growth below the marking scar and all leaves without scars were considered to be new growth. New growth was then dried to constant weight at 60ºC and multiplied by shoot density to determine production per unit area. Benthic community composition was quantified by using Photogrid image analysis software to conduct stratified random point counts in photographs of plots. Stingray feeding pits were noted when observed. Phosphorous content of seagrass was determined via flow injection analysis of new growth tissue collected on March 1st, 2016 with a Lachat QuikChem 8000 at the Northern Arizona University Environmental Analysis Laboratory. Statistical analysis of production and benthic cover was performed using the AOV function in R.

Results

When measured at the end of the experiment simulated grazing led to reduced *T. testudinum* productivity and this reduction was proportional to grazing frequency (Figure 1). Increased grazing frequency also led to reductions in *T. testudinum* percent cover and nearly symmetrical increases in bare sediment percent cover. Other organisms failed to colonize bare space made available by lower *T. testudinum* percent cover (Figure 2). During the experiment stingrays dug

15 feeding pits in highly grazed plots, 7 feeding pits in lightly grazed plots, and no feeding pits in ungrazed plots. Molecular rations of carbon to phosphorous were found to be 1:2 in highly grazed plots, 2:1 in lightly grazed plots, and 2:1 in ungrazed plots. This substantially greater phosphorous availability than the 439:1 carbon to phosphorous ratio needed for balanced growth (Duarte et al. 1995).

Conclusions

That grazing led to lowered seagrass productivity, but no seagrasses showed any signs of phosphorous limitation regardless of treatment suggests that for seagrasses in Bocas del Toro the cost of replacing grazed biomass is greater than any benefit of reduced self-shading they may receive. This may be because Bocas del Toro is a mountainous area that receives more than 3m of rain each year leading to substantial runoff events. These supply nutrients, but reduce environmental light availability. That *T. testudinum* percent cover was reduced along with production in grazing treatments is not surprising, but the failure of other species to colonize the resulting open space was. This may be due to the increase in stingray foraging events in experimentally grazed plots, which could have resulted in the destruction of plants, animals, or algae that could otherwise have successfully colonized. The increase in stingray foraging events agrees with Valentine et al.'s (1994) assertion that stingrays cannot successfully dig holes in undisturbed *T. testudinum* beds, but can uproot *T. testudinum* at bed edges. Apparently sufficiently grazed seagrass is similarly susceptible to bioturbation and further research on how stingrays exploit disturbed seagrass beds is merited.

KEYWORDS: Seagrass, grazing, stingrays, productivity, Panamá

LITERATURE CITED

Duarte, C.M., M. Merino, and M. Gallegos. 1995. Evidence of Iron Deficiency in Seagrasses Growing Above Carbonate Sediments. *Limnology and Oceanography* **40**(6):1153-1158. http://www.jstor.org/stable/2838710.

Fourqurean, J.W. et al. 2010. Effects of excluding sea turtle herbivores from a seagrass bed: Overgrazing may have led to loss of seagrass meadows in Bermuda. *Marine Ecology Progress Series* **419**:223-232.

Holzer, K.K. and K.J. McGlathery. 2016. Cultivation grazing response in seagrass may depend on phosphorus availability. *Marine Biology* **163**(4):88. doi.org/10.1007/s00227-016-2855-5

McClenachan, L., J.B. Jackson, and M.J. Newman. 2006. Conservation implications of historic sea turtle nesting beach loss. *Frontiers in Ecology and Environment* **4**(6):290-296.

Molina Hernández, A.L. and B.I. Van Tussenbroek. 2014. Patch dynamics and species shifts in seagrass communities under moderate and high grazing pressure by green sea turtles. *Marine Ecology Progress Series* **517**:143-157.

Moran, K.L. and K.A. Bjorndal. 2005. Simulated green turtle grazing affects structure and productivity of seagrass pastures. *Marine Ecology Progress Series* **5**:235-247.

Valentine, J.F. et al., 1994. Effects of bioturbation in controlling turtlegrass (*Thalassia testudinum* Banks ex König) abundance: evidence from field enclosures and observations in the Northern Gulf of Mexico. *Journal of Experimental Marine Biology and Ecology* **178**:181-192.

Zieman, J., R. Iverson, and J. Ogden. 1984. Herbivory effects on *Thalassia testudinum* leaf growth and nitrogen content. *Marine Ecology Progress Series* **15**:151-158.

Zieman, J.H.C. 1974. Methods for the study of the growth and production of turtle grass, *Thalassia testudinum* König. *Aquaculture* **4**:139-143.

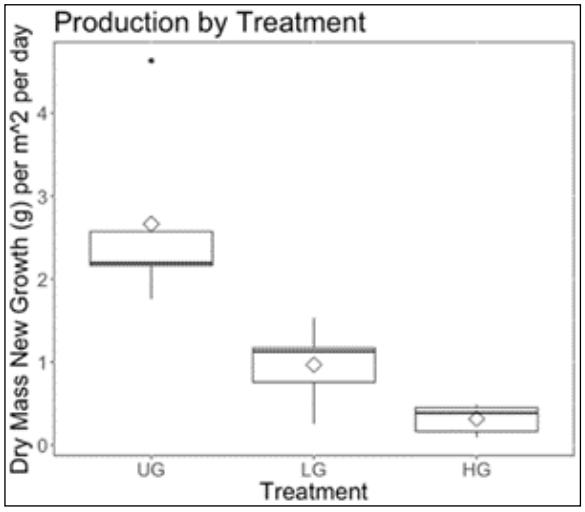

Figure 1. Increased grazing intensity led to decreased *T. testudinum* production. (UG = ungrazed, LG = lightly grazed, HG = highly grazed).

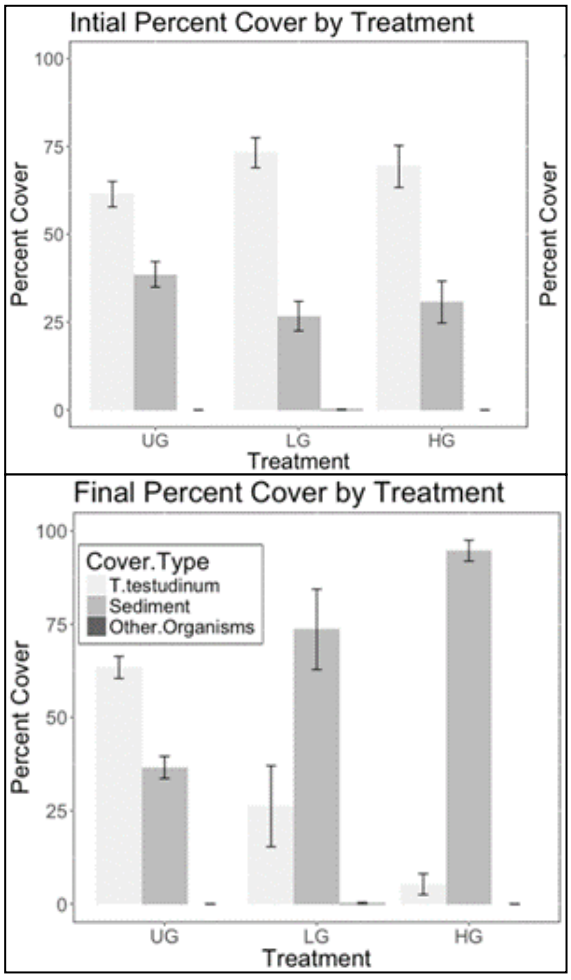

Figure 2. Grazing led to a significant difference between treatments in terms of percent *T. testudinum* cover, but other organisms failed to establish in the newly opened bare sediment.