Evidence of Nitrogen-fueled Blooms of Pelagic *Sargassum* in the Gulf of Mexico

Evidencia de Afloraciones de *Sargassum* Pelágico en el Golfo de México Alimentados de Nitrógeno

Présence D'efflorescences de L'algue Pélagique *Sargassum* Alimentées par des Flux D'azote dans le Golf du Mexique

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EXTENDED ABSTRACT

Introduction

Since 2011, unprecedented strandings of pelagic *Sargassum* have occurred over broad areas of the North Atlantic basin and Caribbean Sea. These strandings, characterized by excessive biomass, are considered to be harmful algal blooms (HABs) as they have a detrimental impact on both the environment (fish kills, dead zones, toxic H_2S) and the tourist-based economies of affected coastal areas. Similar high biomass strandings of *Sargassum* increased during the 1980s and 1990s in the Gulf of Mexico (GOM), impacting coastlines along both Texas and Florida. Research in the late 1980s documented the importance of boundary current circulation between the GOM, Gulf Stream, Sargasso Sea, and Caribbean region to nutrition, productivity and growth of pelagic *Sargassum*. Tissue C:N, C:P, and N:P ratios were significantly lower in neritic (western Caribbean, Florida Current, Gulf Stream) compared to oceanic waters (Sargasso Sea), indicating the importance of land-based nutrient enrichment (Lapointe 1995). The relatively nutrient-enriched plants in the neritic areas also had two-fold higher productivity and much shorter doubling times, indicating nutrient-enhanced growth (Lapointe et al. 2014). Considering the increased strandings of *Sargassum*, the question that arises is: are the increased strandings of *Sargassum* linked, in part, to nutrient enrichment and eutrophication in the GOM?

Methods

To address this question, collections of *Sargassum* for tissue nutrient analysis were made in the wider GOM region in 2010, 2011, and 2012 (Figure 1a). Collections were made from cruises of opportunity following the Deep water Horizon oil spill off Louisiana, the Florida Keys, Texas, as well as offshore waters in the Franklin Eddy. Following collection, *Sargassum* samples were cleaned of epiphytes and epizoa, rinsed briefly with deionized water, and dried in a lab oven at 65°C for 48 - 72 hours. Pre-weighed tissue samples were analyzed for $\delta^{13}C$, $\delta^{15}N$, %N, and % C at the University of California – Davis's Stable Isotope Facility (SIF) using a PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa 20 - 20 isotope ratio mass spectrometer (IRMS; Sercon Ltd., Cheshire, UK). Sub-samples of the powdered macroalgae were analyzed for %P at the Nutrient Analytical Services Laboratory, Chesapeake Biological Laboratory, University of Maryland, Solomons, MD. Tissue P was measured following the methodology of Asplia et al. (1976) using a Technicon Autoanalyzer II with an IBM-compatible, Labtronics, Inc. DP500 software data collection system (D'Elia et al. 1997).

Results and Discussion

These tissue nutrient data indicate that the % N and N:P ratio in *Sargassum* tissue was significantly higher in the GOM, especially during winter 2012, compared to baseline measurements in the Sargasso Sea and neritic waters of the western North Atlantic Ocean in 1986/1987 (Lapointe et al. 2014). *S. fluitans* %N increased significantly from 0.67 in the oceanic baseline study, 1.01 in the neritic region, to a peak of 2.28 in the GOM in winter 2012. All of the *S. fluitans* data collected in the GOM were significantly higher than the oceanic baseline data. The N:P ratio in both *S. fluitans* and *S. natans* was significantly higher in the GOM measurements than the baseline measurements. In *S. fluitans* the N:P ratio increased from a low of 9.61 in the neritic baseline measurements to a high of 39.58 in the GOM in winter 2012. *S. natans* increased from a low of 10.07 in the neritic baseline measurements to 34.49 in GOM 2011. The %P measurements in *S. fluitans* and *S. natans* were not significantly higher in the GOM than the baseline study and did not exhibit a trend similar to those seen in the %N and N:P data. Although these *Sargassum* data are from different regions and years, the significant increases in %N and N:P ratios it illustrates in the GOM supports the hypothesis that the Mississippi and Atchafalaya rivers are major sources of N enrichment (Lapointe 1995). The combined annual mean streamflow for the Mississippi and Atchafalaya Rivers represents about 80 percent of the estimated freshwater discharge to the GOM; these two rivers account for an estimated 90 percent of total N load and 87 percent of the total P load discharged annually to the GOM (Dunn, 1996). Increasing nitrogen (mostly nitrate) along with other nutrients have been implicated as a cause of hypoxia in a large zone along the Louisiana-Texas coast (Turner and Rabalais 1991, Rabalais et. al. 1996). In addition, the N:P ratio of the Mississippi River and northern GOM increased from 9 to 15 and 16 to 24, respectively, between 1960s and the 1980s (Rabalais et al. 1996).

Increased biomass production of *Sargassum* in the GOM could also contribute to standing crop of *Sargassum* in the North Atlantic basin and Caribbean Sea. Remote sensing measurements showed that extensive pelagic *Sargassum* biomass accumulated in the NW GOM in the winter/spring between 2010 and 2012 (Figure 1b). Gower and King (2008, 2011) used the MERIS satellite sensor to map the distribution of pelagic *Sargassum* at a spatial resolution of 1.2 km. Daily images were merged into monthly intervals, and the images show the origin of accumulations of *Sargassum* in March in the NW GOM and eastward progression and eventual advection into the Atlantic Ocean, Florida Current, Gulf Stream and Sargasso Sea, extending to about 45˚W by September. This suggests that a *Sargassum* "growth continuum" begins in the GOM and follows the Loop Current around the Florida Keys and then north to the Gulf Stream, Sargasso Sea, Canaries Current, North Equatorial Current, and ultimately the Caribbean region. These studies point to the importance of the GOM as a bioreactor for nutrient-enriched growth and productivity of *Sargassum*, which could be a significant factor contributing to the unprecedented *Sargassum* strandings in the Atlantic basin and Caribbean Sea since 2011.

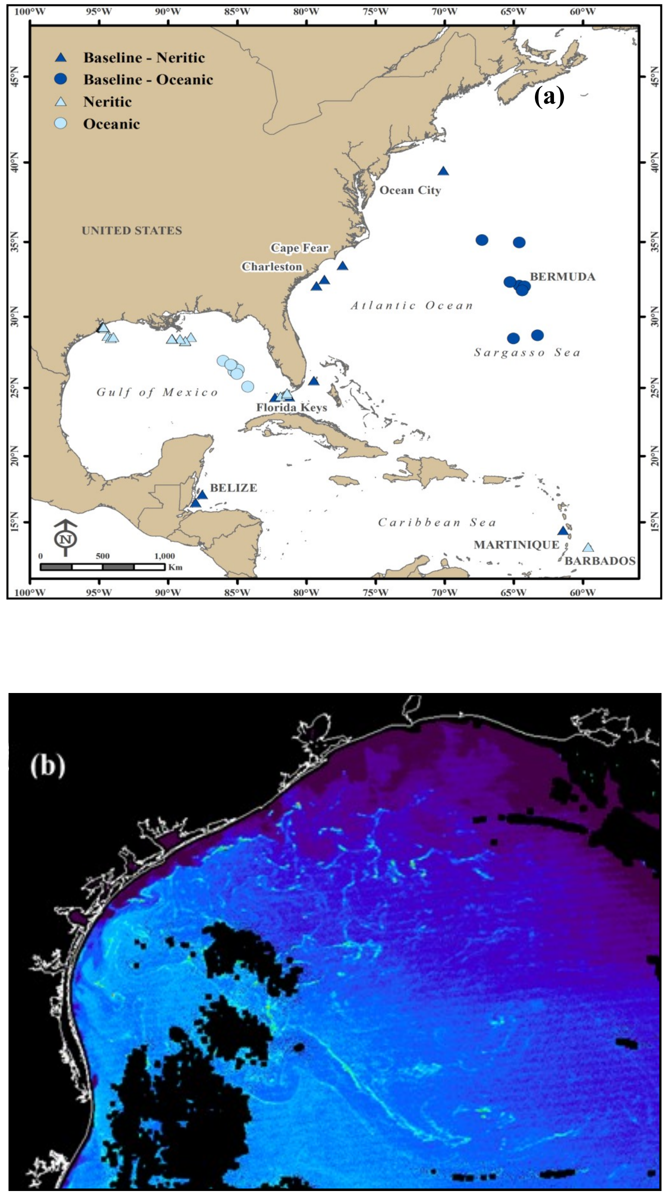

Figure 1. (a) Sampling stations in the GOM region and baseline stations in the Gulf Stream, Sargasso Sea, and Caribbean region. (b) MODIS satellite image of *Sargassum* slicks in the western GOM, May 22, 2012.

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